NISTIR 88-4020

Center for Electronics and Electrical Engineering

Technical Progress Bulletin

Covering Center Programs,
July to September 1988,
with 1989 CEEE Events Calendar

88-3

January 1989

U.S. Department of Commerce
National Institute of Standards and Technology
National Engineering Laboratory
Gaithersburg, Maryland 20899

INTRODUCTION TO THE JANUARY 1989 ISSUE OF THE CEEE TECHNICAL PROGRESS BULLETIN

This is the twenty-fourth issue of a quarterly publication providing information on the technical work of the National Institute of Standards and Technology (formerly the National Bureau of Standards) Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Progress Bulletin covers the third quarter of calendar year 1988.

Organization of Bulletin: This issue contains abstracts for all Center papers released for publication by NIST in the quarter and citations and abstracts for Center papers published in the quarter. Entries are arranged by technical topic as identified in the Table of Contents and alphabetically by first author under each subheading within each topic. At times, an abstract may appear in several different categories. Unpublished papers appear under the subheading "Released for Publication". Papers published in the quarter appear under the subheading "Recently Published". Following each abstract is the name and telephone number of the individual to contact for more information on the topic (usually the first author). For the information of our readership, this issue also contains, in the Additional Information section, entries covering work by other parts of NIST on DC and Low-Frequency Metrology and Fundamental Electrical Measurements. A calendar of Center conferences and workshops planned for calendar year 1989 and a list of sponsors of the work are also included at the end of the Bulletin.

Center for Electronics and Electrical Engineering: Center programs provide national reference standards, measurement methods, supporting theory and data, and traceability to national standards.

The metrological products of these programs aid economic growth by promoting equity and efficiency in the marketplace, by removing metrological barriers to improved productivity and innovation, by increasing U.S. competitiveness in international markets through facilitation of compliance with international agreements, and by providing technical bases for the development of voluntary standards for domestic and international trade. These metrological products also aid in the development of rational regulatory policy and promote efficient functioning of technical programs of the Government.

The work of the Center is divided into two major programs: the Semiconductor Technology Program, carried out by the Semiconductor Electronics Division in Gaithersburg, MD, and the Signals and Systems Metrology Program, carried out by the Electrosystems Division in Gaithersburg and the Electromagnetic Fields and Electromagnetic Technology Divisions in Boulder, CO. Key contacts in the Center are given on the back cover; readers are encouraged to contact any of these individuals for further information. To request a subscription or for more information on the Bulletin, write to CEEE Technical Progress Bulletin, National Institute of Standards and Technology, Metrology Building, Room B-358, Gaithersburg, MD 20899 or call (301) 975-2220.

Center sponsors: The Center Programs are sponsored by the National Institute of Standards and Technology and a number of other organizations, in both the Federal and private sectors; these are identified on page 32.

Note on Publication Lists: Guides to earlier as well as recent work are the publication lists covering the work of each division. These lists are revised and reissued on an approximately annual basis and are available from the originating division. The current set is identified in the Additional Information section, page 28.

TABLE OF CONTENTS

INTRODUCTION . . . . . inside front cover

SEMICONDUCTOR TECHNOLOGY PROGRAM 2

Silicon Materials 2
Analysis Techniques 2
Dimensional Metrology 2
Photodetectors 4
Integrated Circuit Test Structures 4
Device Physics and Modeling 4
Insulators and Interfaces 5
Packaging 5
Other Semiconductor Metrology Topics 6

FAST SIGNAL ACQUISITION, PROCESSING, & TRANSMISSION 6

Waveform Metrology 6
Cryoelectronic Metrology 7
Pulse Power Metrology 9
Antenna Metrology 9
Microwave and Millimeter-Wave Metrology 14
Optical Fiber Metrology 15
Electro-Optic Metrology 16
Other Fast Signal Topics 16

ELECTRICAL SYSTEMS 18

Power Systems Metrology 18
Superconductors 21

ELECTROMAGNETIC INTERFERENCE 26

Radiated Electromagnetic Interference 26
Conducted Electromagnetic Interference 27

ADDITIONAL INFORMATION 28

1989 CEEE CALENDAR 32

SPONSOR LIST 33

KEY CONTACTS IN CENTER, CENTER ORGANIZATION . . . . . back cover

SEMICONDUCTOR TECHNOLOGY

Silicon Materials

Released for Publication

Geist, J., **Study of the Infrared Absorption Cross Section of Arsenic in Silicon as a Function of Concentration at 0 K.**

The spectral dependence of the absorption cross section of As in Si near 0 K has been determined from infrared transmission measurements for three As concentrations (5.3, 8.4, and 15.9 x 10^{17} cm^{-3}) in the impurity band regime. The results demonstrate some features of physical interest. With increasing As concentration, the lines associated with the intra-atomic transitions broaden asymmetrically, while the integral of the total absorption cross section over photon energy is conserved as required by the oscillator-strength sum rule. It thus appears that the cross section for the intra-atomic transitions is conserved as the lines hybridize with the continuum. Comparison of our results with photoionization cross-section data suggests that the lines contribute to the cross section for photoionization through field and thermally assisted transitions when they are near the threshold for photoionization.
[Contact: Jon Geist, (301) 975-2066]

Analysis Techniques

Released for Publication

Bouldin, C.E., Carter, A.C., Kirkland, J., and Neiser, R., **Silicon Photodiode Detectors for EXAFS**, to be published in the Proceedings of XAFS V Conference, Seattle, Washington, August 22-26, 1988.

Results are shown of using a large-area silicon diode as a fluorescence detector for extended x-ray absorption fine-structure (EXAFS) measurements. A direct comparison of this diode detector relative to a gas ionization fluorescence detector is made. Advantages of the diode detector include: higher signal for a given photon flux (due to higher quantum efficiency), vacuum and cryogenic compatibility, freedom from microphonic noise, good linearity, extremely wide dynamic range, operation without high voltage or gas connections, very simple electronics, and low cost. Use of photodiodes for transmission EXAFS is discussed.
[Contact: Charles E. Bouldin, (301) 975-2046]

Dimensional Metrology

Released for Publication

Postek, M.T., Keery, W.J., and Larrabee, R.D., **Specimen Biasing to Enhance or Suppress Secondary Electron Emission from Charging Specimens at Low Accelerating Voltages.**

Specimen biasing is shown to produce improved images in the scanning electron microscope at low-beam energies (0.8 to 2.5 keV) when charging effects, topographic effects, or detector shadowing effects would otherwise be present. Examples of such improvement are given for gallium arsenide field-effect transistors (positive charging), patterned photoresist layers on silicon wafers (negative charging and shadowing in contact holes), fractured lucite (negative charging), polyethylene wrapper material (positive charging), and polished diamond tools (positive charging). It is concluded that specimen biasing may be a simpler and more convenient way to achieve some of the advantages of the converted backscattered secondary electron technique for imaging, but without some of the fundamental disadvantages of that technique. Characterization of this backscattered electron-derived image bears further investigation for possible metrological applications.
[Contact: Michael T. Postek, (301) 975-2299]

Dimensional Metrology (cont'd.)

Postek, M.T., Larrabee, R.D., and Keery, W.J., **A New Approach to Accurate X-Ray Mask Measurement in an SEM.**

This paper presents the concept and some preliminary experimental data of a new method for measuring critical dimensions on masks used for x-ray lithography. The method uses a scanning electron microscope (SEM) in a transmitted-electron imaging mode and can achieve nanometer precision. Use of this technique in conjunction with measurement algorithms derived from electron-beam interaction modeling may ultimately enable measurements of these masks to be made to nanometer accuracy.
[Contact: Michael T. Postek, (301) 975-2299]

Recently Published

Larrabee, R.D., **Submicrometer Optical Metrology**, Proceedings of the 46th Annual Meeting of the Electron Microscopy Society of America, Milwaukee, Wisconsin, August 8-9, 1988 (San Francisco Press, 1988), pp. 50-51.

The National Institute of Standards and Technology has had a continuing program for over 10 years to develop optical feature-size standards for the integrated circuit industry. In this paper, the basic obstacles that must be overcome to achieve precision and accuracy for submicrometer feature-size measurements are surveyed, and the present (and projected future) standards for micrometer and submicrometer optical dimensional metrology are discussed.
[Contact: Robert D. Larrabee, (301) 975-2298]

Nyyssonen, D., and Kirk, C., **Optical Microscope Imaging of Lines Patterned in Thick Layers with Variable Edge Geometry: Theory** [original title: Modeling of the Optical Microscope Imaging of Lines Patterned in Thick Layers with Variable Edge Geometry], Journal of the Optical Society of America, Vol. 5, pp. 1270-1280 (August 1988).

A monochromatic, waveguide model is presented which can predict the optical microscope images of line objects with arbitrary edge geometry, patterned in thick layers, including multilayer structures with sloping, curved, and undercut edges, granular structures such as lines patterned in polysilicon, as well as asymmetric objects. The model is used to illustrate the effects of line edge structure on the optical image. Qualitative agreement with experimentally obtained optical image profiles is demonstrated. Application of the model to study the effects of variations in layer thickness and edge geometry on linewidth measurements made at different stages of manufacturing integrated circuit devices is discussed.
[Contact: Robert D. Larrabee, (301) 975-2298]

Postek, M.T., and Tibero, R.C., **Low Accelerating Voltage SEM Magnification Standard Prototype**, Proceedings of the 46th Annual Meeting, Electron Microscopy Society of America, Milwaukee, Wisconsin, August 8-9, 1988 (San Francisco Press, 1988), pp. 198-199.

NIST has recently begun a cooperative effort with the National Nanofabrication Facility at Cornell University to fabricate a new scanning electron microscope (SEM) magnification standard by electron-beam lithography. The design of the standard is such that integrated structures in both the x- and y-directions can be used to calibrate the scans of the SEM. Structures with a nominal pitch as large as 3000 μm to as small as a nominal pitch of 0.20 μm permit calibration from the lowest magnification range to in excess of 200,000X. Prototype samples, designed both to test manufacturability and the ability to solve the present problems with SRM 484 were fabricated on semiconductor wafers. The etched silicon structures demonstrate good contrast throughout the accelerating

Dimensional Metrology (cont'd.)

voltage range. This paper outlines the design criteria and the work being done to produce and certify this as an SEM magnification standard.
[Contact: Michael T. Postek, (301) 975-2299]

Photodetectors

Released for Publication

Bouldin, C.E., Carter, A.C., Kirkland, J., and Neiser, R., **Silicon Photodiode Detectors for EXAFS**, to be published in the Proceedings of XAFS V Conference, Seattle, Washington, August 22-26, 1988.

Results are shown of using a large-area silicon diode as a fluorescence detector for extended x-ray absorption fine-structure (EXAFS) measurements. A direct comparison of this diode detector relative to a gas ionization fluorescence detector is made. Advantages of the diode detector include: higher signal for a given photon flux (due to higher quantum efficiency), vacuum and cryogenic compatibility, freedom from microphonic noise, good linearity, extremely wide dynamic range, operation without high voltage or gas connections, very simple electronics, and low cost. Use of photodiodes for transmission EXAFS is discussed.
[Contact: Charles E. Bouldin, (301) 975-2046]

Integrated Circuit Test Structures

Released for Publication

Zaghloul, M.E., Khera, D., Linholm, L.W., and Reeve, C.P., **A Machine-Learning Classification Approach for IC Manufacturing Control Based on Test Structure Measurements.**

This paper describes the use of a machine-learning method for classifying electrical measurement results from a custom-designed test chip. These techniques are used for characterizing the performance of a 1-μm integrated circuit lithography process. The focus of the work is to develop a method for producing reliable classification rules from data bases containing large samples of measurement data. The paper describes a test chip, data-handling methods, rule generation techniques, and statistical data reduction and parameter extraction techniques. An analysis of error introduced by noise in the rule formation process is presented.
[Contact: Mona E. Zaghloul, (301) 975-2239]

Recently Published

Schafft, H.A., Lechner, J., Sabi, B., and Smith, R., **How Good Are Your Estimates of t_{50} and σ?**, Proceedings of the 1987 Wafer Reliability Workshop, O. D. Trapp, Ed., Lake Tahoe, California, October 25-28, 1987, pp. 165-174.

A transcript of a talk concerning statistics for electromigration testing is presented. The talk served as a forerunner of a paper published in the Proceedings of the 26th Annual Reliability Physics Symposium, April 11-14, 1988, pp. 192-202.
[Contact: Harry A. Schafft, (301) 975-2234]

Device Physics and Modeling

Released for Publication

Lowney, J.R., and Bennett, H.S., **Effects of Doping-Density Gradients on Band-Gap Narrowing in Silicon and GaAs Devices.**

The limitations of the theory for band-gap narrowing, which is based on uniform material, are considered in devices that have steep doping gradients. Validity criteria are derived that place upper bounds on the dopant and carrier density gradients for the application of the results from uniform theory. The existence of wavefunction tailing beyond the potential barriers

Device Physics & Modeling (cont'd.)

that occur in devices is studied. At room temperature the effects due to these tails are usually small, but at low temperatures they can become very significant.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

Insulators & Interfaces

Released for Publication

Bouldin, C.E., **EXAFS Study of a Buried Germanium Layer in Silicon,** to be published in the Proceedings of the XAFS V Conference, Seattle, Washington, August 22-26, 1988.

EXAFS (extended x-ray absorption fine-structure) measurements are made of a 200 Å layer of Ge on a Si substrate. The Ge layer is covered by a 3000 Å layer of SiO_2. Sensitivity to the buried layer is enhanced through the use of grazing incidence fluorescence detection. A two-channel photodiode detector is used to detect the fluorescence and to discriminate against Bragg peaks from the single-crystal Si substrate. Since the fluorescence signal is isotropic, while the Bragg peaks are directional, one channel of the detector is always free of Bragg peak interference. We determine the average number of Ge-Ge and Ge-Si neighbors in the buried Ge layer, the distances, and disorder in the first-shell. Prospects for studying the buried Ge-SiO_2 interface are discussed.
[Contact: Charles E. Bouldin, (301) 975-2046]

Candela, G.A., Chandler-Horowitz, D., Marchiando, J.F., Novotny, D.B., Belzer, B.J., and Croarkin, M.C., **Standard Reference Materials: Preparation and Certification of SRM-2530, Ellipsometric Parameters Δ and ψ and Derived Thickness and Refractive Index of a Silicon Dioxide Layer on Silicon,** to be published as NIST Special Publication 260-109.

A Standard Reference Material, SRM-2530, has been designed, fabricated, and certified for the ellipsometric parameters delta, Δ, and psi, ψ, and for the derived thickness and refractive index of a silicon dioxide layer on silicon using a highly accurate ellipsometer built at NIST. This SRM is issued primarily to evaluate the accuracy of ellipsometers. The SRM consists of a 76-mm (three-inch) diameter silicon wafer with a silicon dioxide layer of one of three uniform thicknesses, 50, 100, or 200 nm. The design and fabrication of the SRM are presented along with the ellipsometric technique and data analysis leading to certification of this SRM. A least-squares method minimizing the deviations in Δ and ψ between the experimental values and those calculated from a model has been used in certifying the SRM. The derived values of the thickness and refractive index may be determined by using either a two-layer or a one-layer model. The two-layer model consists of a silicon dioxide layer on a thin interlayer atop the silicon substrate, whereas the one-layer model assumes a single dielectric layer for the silicon dioxide without the interlayer. The two-layer modeling analysis gives better agreement to the collective multiple-sample experimental data than does the one-layer modeling analysis, and gives a value for the refractive index of the silicon dioxide layer that is independent of thickness. Therefore, the certified values of thickness and refractive index are based on the two-layer model.
[Contact: Deane Chandler-Horowitz, (301) 975-2084]

Packaging

Released for Publication

Harman, G.G., **The Silicon and Gallium Arsenide Cratering Problem,** to be published in the Conference Proceedings of the VLSI and GaAs Packaging Workshop, Santa Clara, California, September 12-14, 1988.

Packaging (cont'd.)

The complex synergystic cratering effects of the VLSI era involve not only bonding parameters, but also Au-Al compound-induced stress, silicon nodules in the metallization, plastic package stress, and surface mount stress. The situation is even worse in GaAs.
[Contact: George G. Harman, (301) 975-2097]

Other Semiconductor Metrology Topics

Released for Publication

Bouldin, C.E., Bunker, G., McKeown, D.A., Ritter, J.J., and Forman, R.A., **Multiple Scattering in the XANES** [X-ray Absorption Near Edge Structure] **of Tetrahedral Germanium Gases,** to be published in the Proceedings of the XAFS V Conference, Seattle, Washington, August 22-26, 1988.

X-ray absorption fine-structure (XAFS or EXAFS (E = Extended)) measurements of $GeCl_4$, GeH_3Cl, and GeH_4 are reported. Since wide-angle multiple scattering (MS) involving H atoms is negligible, we experimentally isolate the single and MS terms in the XAFS of $GeCl_4$ by comparison of the spectra of the three compounds. We find that MS is nowhere dominant over single scattering (SS), although within 15 eV of the edge the two are comparable in size. However, the MS damps out very quickly with increasing energy above the absorption edge. Beyond 40 eV past the edge the MS/SS ratio is less than 0.06. Our calculations are found to be in qualitative agreement with experiment, but overestimate the size and energy range of the MS. Our results suggest that XAFS data in the range $1<K<3$ $Å^{-1}$ can be analyzed in an SS picture in many cases, as long as good standard compounds are used, and calculations are used to estimate possible errors due to neglect of MS. We also report the first evidence of single scattering observed from H atoms.
[Contact: Charles E. Bouldin, (301) 975-2046]

FAST SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

Waveform Metrology

Recently Published

Oldham, N.M., Hetrick, P.S., and Xiangren, Z., **A Calculable, Transportable Audio-Frequency AC Reference Standard**, Conference Digest of CPEM'88, 1988 Conference on Precision Electromagnetic Measurements, Tsukuba Science City, Japan, June 7-10, 1988, pp. 46-47 (IEEE, New York, New York, June 1988).

A transportable ac voltage source is described, in which sinusoidal signals are digitally synthesized in the audio-frequency range. The rms value of the output waveform may be calculated by measuring the dc level of the individual steps used to generate the waveform. The uncertainty of this calculation is typically ±10 ppm from 20 Hz to 10 kHz at the 7-V level.
[Contact: Nile M. Oldham, (301) 975-2408]

Oldham, N.M., Petersons, O., and Waltrip, B.C., **Audio-Frequency Current-Comparator Power Bridge**, Conference Digest of CPEM'88, 1988 Conference on Precision Electromagnetic Measurements, Tsukuba Science City, Japan, June 7-10, 1988, p. 48 (IEEE, New York, New York, June 1988).

A system for performing active and reactive power measurements from 50 Hz to 20 kHz is described. The technique is an extension of a power bridge based on a current-comparator capacitance bridge that was originally restricted to power frequencies. A digitally synthesized dual-channel signal source provides the required voltage and current signals.
[Contact: Nile M. Oldham, (301) 975-2408]

Souders, T.M., and Hetrick, P.S., **Accurate RF Voltage Measurements Using**

Waveform Metrology (cont'd.)

a **Sampling Voltage Tracker**, Conference Digest of CPEM-88, 1988 Conference on Precision Electromagnetic Measurements, Tsukuba Science City, Japan, June 7-10, 1988, pp. 270-271 (IEEE, New York, New York, June 1988).

The radio-frequency (rf) voltage measurement capability of an equivalent time-sampling system is described. The frequency range investigated is 1 to 100 MHz. Over this range, the measured errors, determined by ac/dc thermal transfer, are within the stated uncertainties presently provided by NIST for thermal converter calibrations. The system offers several advantages over conventional thermal transfer techniques: ac/dc transfers are not required, loading and transmission line problems are reduced, and direct measurement of voltages from 2 V to as low as 10 mV are possible.
[Contact: T. Michael Souders, (301) 975-2406]

Cryoelectronic Metrology

Released for Publication

Cromar, M.W., Beall, J.A., Go, D., Masarie, K.A., and Ono, R.H., **Noise in DC SQUIDs with Nb/Al-Oxide/Nb Josephson Junctions.**

We have developed a process which incorporates very high-quality Nb/Al-oxide/Nb Josephson junctions. The junctions have low subgap conductance yielding V_m (quality factor defined as the product of the subgap resistance and the theoretical critical current as deduced from the normal-state resistance) greater than 50 mV for critical current densities of 1000 A/cm^2. Low-inductance superconducting quantum interference devices (SQUIDs) made with these junctions were apparently free from junction conductance fluctuations, at least for frequencies above 1 Hz. The SQUIDs exhibited flux noise of currently unknown origin.
[Contact: Michael W. Cromar, (303) 497-5375]

Dhere, N.G., Goral, J.P., Mason, A.R., Dhere, R.G., and Ono, R.H., **Single-Target Magnetron Sputter-Deposition of High-T_c Superconducting Bi-Sr-Ca-Cu-O Thin Films.**

A single-target radio-frequency magnetron sputtering was used to deposit superconducting thin films of Bi-Sr-Ca-Cu-O with a transition temperature above 80 K. Varying the oxygen partial pressure modified the concentrations of Bi, Cu, and O in the films by 10 to 20%. Higher annealing temperatures, especially with brief melting, favored the formation of the higher T_c phases. Tetragonal phases (6-K and 75-K T_c), with a = 3.8097 Å, C = 24.607 Å, and $Bi_2Sr_2CuO_6$ composition, and a = 3.812 Å, c = 30.66 Å, and $Bi_2Sr_{2-x}Ca_{1+x}Cu_2O_8$ composition, were identified; 70 to 84 K films contained large proportions of a new tetragonal phase, with a = 3.81 Å and c = 55.23 Å.
[Contact: Ronald H. Ono, (303) 497-3762]

Hu, Q., Mears, C.A., Richards, P.L., and Lloyd, F.L., **MM Wave Quasioptical SIS Mixers.**

We have tested the performance of planar superconductor-insulator-superconductor (SIS) mixers with log-periodic antennas at millimeter and submillimeter wave frequencies from 90 to 360 GHz. The large $\omega R_N C$ product ($\simeq$ 10 at 90 GHz) of our $Nb/NbO_x/Pb$-In-Au junctions requires an integrated inductive tuning element to resonate the junction capacitance at the operating frequencies. We have used two types of integrated tuning element, which were designed with the aid of measurements using Fourier transform spectroscopy. Preliminary results indicate that the tuning elements can give very good mixer performance up to at least 200 GHz. An inductive wire in parallel with a 5-junction array, gives a minimum mixer noise temperature of 115 K (double-side-band [DSB]) at 90 GHz

Cryoelectronic Metrology (cont'd.)

with a full-width-at-half-maximum (FWHM) bandwidth of 8 GHz. An open-ended microstrip stub, in parallel with a single junction, gives minimum mixer noise temperatures of 150 and 200 K (DSB) near 90 and 180 GHz with FWHM bandwidths of 4 and 3 GHz, respectively. The relatively high mixer noise temperatures compared to those of waveguide SIS mixers in a similar frequency range are attributed mainly to the losses in our optical system, which is being improved.
[Contact: Frances L. Lloyd, (303) 497-3254]

Kautz, R.L., and Monaco, R., **Chaos and Catastrophe Near the Plasma Frequency in the RF-Biased Josephson Junction.**

At bias frequencies much higher than the plasma frequency, the zero-voltage state of the rf-biased Josephson junction is known to span a range of dc bias proportional to the zero-order Bessel function of the rf amplitude. This pattern is modified at frequencies near the plasma frequency by the onset of chaotic instabilities and by the presence of cusp catastrophes.
[Contact: Richard L. Kautz, (303) 497-3391]

Ono, R.H., Beall, J.A., Cromar, M.W., Mankiewich, P.M., Howard, R.E., and Skocpol, W., **Switching Noise in $YBa_2Cu_3O_x$ Macrobridges.**

We have observed intermittent switching in the voltage-current characteristics of $YBa_2Cu_3O_x$ micro-constrictions. This indicates that at a given bias point, there are multiple metastable voltage states with lifetimes which depend on the bias current and applied magnetic field. The microbridges are made of thin (<500 nm), polycrystalline films of $YBa_2Cu_3O_x$ which are patterned by liftoff into structures with dimensions ranging from less than 1 μm to 100 μm. Details of the fabrication process and the measurements are presented. The results are discussed in the context of fluctuations in the effective resistance of the bridge due to motion of trapped flux.
[Contact: Ronald H. Ono, (303) 497-3762]

Sauvageau, J.E., and McDonald, D.G., **Superconducting Kinetic Inductance Bolometer.**

We are developing a bolometer with a temperature sensor based on the temperature dependence of the inductance of a superconducting microstrip line. As a first step in exploring this idea experimentally, we have designed experiments to test only the temperature sensor. The experimental devices are all-niobium inductance thermometers fabricated on silicon substrates which have been deeply etched to provided areas of relative thermal isolation. The ground plane superconductor is thin enough that its kinetic inductance dominates the audio-frequency impedance of the stripline near its critical temperature, i.e., at 0.9 T_c. This differential thermometer uses a commercial superconducting quantum interference device (SQUID) as the preamplifier. Results from the first experiments with these devices are given.
[Contact: Joseph E. Sauvageau, (303) 497-3988]

Recently Published

Kautz, R.L., **Thermally Induced Escape: The Principle of Minimum Available Noise Energy**, Physical Review A, Vol. 38, No. 4, pp. 2066-2080 (August 15, 1988).

The average time required for thermally induced escape from a basin of attraction increases exponentially with inverse temperature in proportion to exp (E_A/kT) in the limit of low temperature. A minimum principle states that the activation energy E_A is the minimum available noise energy required to execute a state-space trajectory which

Cryoelectronic Metrology (cont'd.)

takes the system from the attractor of the noise-free system to the boundary of its basin of attraction and that the minimizing trajectory is the most probable low-temperature escape path. This principle is applied to the problem of thermally induced escape from two attractors of the dc-biased Josephson junction, the zero-voltage state and the voltage state, to determine activation energies and most probable escape paths. These two escape problems exemplify the classical case of escape from a potential well and the more general case of escape from an attractor of a nonequilibrium system. Monte Carlo simulations are used to verify the accuracy of the activation energies and most probable escape paths derived from the minimum principle.
[Contact: Richard L. Kautz, (303) 497-3391/-3988]

Pulse Power Metrology

Released for Publication

Olthoff, J.K., and Hebner, R.E., **Strategic Defense Initiative (SDI) Space Power Systems Metrology Assessment,** to be published in the Proceedings of the 6th Symposium on Space Nuclear Power Systems, Albuquerque, New Mexico, January 9-12, 1989.

SDI space power requirements demand high reliability and operation over many orders of magnitude of both amplitude and time. While current technology is suitable for making many of these measurements, achieving acceptable levels of accuracy for some parameters will require considerable research and development. We have attempted to identify areas of the SDI program where the metrology requirements presently exceed state-of-the-art capabilities.
[Contact: James K. Olthoff, (301) 975-2431]

Recently Published

McKnight, R.H., **Conference Record of the Workshop on Measurement of Electrical Quantities in Pulse Power Systems II,** Gaithersburg, Maryland, March 5-7, 1986, R. H. McKnight, Ed., 101 pages (IEEE, New York, 1988).

The purpose of this workshop was to encourage the exchange of information about measurements of electrical quantities in pulse power systems between those individuals who are presently working in this area and those of the pulse power community who have a general interest in such measurements. The format of the meeting included oral presentations of papers, some of which were submitted for publication and are included in this proceedings, progress reports, and discussion sessions. Discussion sessions were recorded with the permission of the attendees, edited by the discussers and are published as part of the proceedings. Several papers were withdrawn because of difficulties in obtaining sponsor clearances, and a roundtable discussion held on the last day of the workshop has been omitted from the proceedings at the request of some of the participants. The papers have been published as submitted and the authors retain sole responsibility for the contents.
[Contact: William E. Anderson, (301) 975-2423]

Antenna Metrology

Recently Published

Baird, R.C., Newell, A.C., and Stubenrauch, C.F., **A Brief History of Near-Field Measurements of Antennas at the National Bureau of Standards,** IEEE Transactions on Antennas and Propagation, Vol. 36, No. 6, pp. 727-733 (June 1988).

The National Bureau of Standards (NBS) played a pioneering role in the development of practical planar near-field antenna measurement techniques. This paper presents a brief history of that role, which began with theoretical

Antenna Metrology (cont'd.)

studies to determine corrections for diffraction in a microwave measurement of the speed of light. NBS contributions to the development of nonplanar near-field measurement theory and practice are also described.
[Contact: Ramon C. Baird, (303) 497-3131]

Camell, D.G., Larsen, E.B., and Anson, W.J., **NBS Calibration Procedures for Horizontal Dipole Antennas (25 to 1000 MHz)**, Symposium Record of the 1988 IEEE International Symposium on Electromagnetic Compatibility, Seattle, Washington, August 2-4, 1988, pp. 390-394 (1988).

The theoretical basis and test procedures for horizontally polarized dipole calibrations at the National Bureau of Standards are described. Two different techniques and two different test sites are used for these measurements. The standard antenna method uses the calculation of a field strength level, from the response of a simple half-wave dipole, to calibrate an antenna. This method is used at an open-field site in the frequency range 25 to 1000 MHz. The standard field method applies the theoretical gain equations of waveguides to determine the field strength level. This latter method is used in an anechoic chamber in the frequency range 200 to 1000 MHz. Procedures for both techniques are explained and measurement setups are illustrated. Measurement uncertainties are discussed.
[Contact: Dennis G. Camell, (303) 497-3214]

FitzGerrell, R.G., **Three PC-Computer Programs for Antenna Calculations Primarily for Use Below 1000 MHz**, IEEE Antennas and Propagation Society Newsletter, Vol. 29, No. 3, pp. 30-32 (June 1987).

This article describes three computer programs used frequently by the author when working on various antenna measurement projects in the frequency range below 1000 MHz. These programs were originally written in FORTRAN 4 and run on various main-frame computers at the NIST Boulder Laboratories. During the last year, they were converted, essentially intact, to FORTRAN 77 and compiled using IBM Professional FORTRAN installed on an IBM PC/XT. As a result of this choice of compilers, a math co-processor is required (8087 for the XT) to run the *.EXE files.
[Contact: Allen C. Newell, (303) 497-3743]

FitzGerrell, R.G., **Monopole Impedance and Gain Measurements on Finite Ground Planes**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 3, pp. 431-438 (March 1988).

The purpose of the work described here is to determine if it is possible to make "acceptably accurate" input impedance and gain measurements of monopoles on a reduced ground plane. Ideally, monopoles are located on an infinite, perfectly conducting, ground plane. Practically, measurements are made on a test site with dimensions largely determined by the cost and availability of the space occupied by the site. Measured and calculated data show that the diameter of a highly conducting ground plane should be at least 4 λ, where λ = wavelength, for measuring the input impedance of 0.25-λ monopoles. At 25 MHz, the lowest frequency considered here, such a ground plane would require a space at least 48 m in diameter. Model impedance measurements and calculations presented here imply that a space only 10 m by 11 m is required by using 16 resistively loaded wire radials to extend a 3.66-m by 4.88-m rectangular aluminum ground plane. Measured insertion loss data acquired using a 1:5 scale model ground plane with resistively loaded radials indicate that it is sufficiently large for gain measurements as well. Measured and calculated monopole standing-wave ratio and insertion loss of a full-scale ground plane verify the results of the

Antenna Metrology (cont'd.)

model measurements.
[Contact: Mark T. Ma, (303) 497-3800]

Francis, M.H., and Stubenrauch, C.F., **Comparison of Measured and Calculated Antenna Side Lobe Coupling Loss in the Near Field Using Approximate Far-Field Data**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 3, pp. 438-441 (March 1988).

Computer programs exist to calculate the coupling loss between two antennas provided that the amplitude and phase of the far field are available. However, for many antennas the complex far field is not known accurately. In such cases it is nevertheless possible to specify approximate far fields from a knowledge of the side lobe level of each antenna along the axis of separation, and the electrical size of each antenna. Measurements of near-field coupling loss between two moderate sized microwave antennas were taken to determine the effectiveness of using approximate side-lobe level data instead of the detailed far fields. Comparison of the measured results to those from the computer program ENVLP indicates that the use of approximate far fields gives an estimate of the coupling loss with an uncertainty of about ±5 dB.
[Contact: Michael H. Francis, (303) 497-5873]

Hill, D.A., **Antennas for Geophysical Applications**, Antenna Handbook: Theory, Applications, and Design, Chapter 23, pp. 23-1 to 23-26, Y.T. Lo and S.W. Lee, Eds. (Van Nostrand Reinhold Co., 1988).

The use of electrical methods in geophysics has expanded greatly in the past two decades, and during the same time period an interest in subsurface communication has developed. Both geophysical prospecting and underground communication require transmission of signals into the earth and, as a result, the same antenna types are used for both applications.

Because the methods and antennas used in geophysical probing are so varied, it is not possible to attempt a comprehensive discussion in one chapter. However, if we limit the applications to deep, subsurface probing and to through-the-earth communication, then the antennas used are primarily of two types: straight-wire antennas which are grounded at the end points and wire-loop antennas. Sections 2 and 3 discuss grounded wire antennas for direct current and time-varying excitations, respectively. Section 4 discusses loop antennas. In the analysis and discussion of these antennas some applications in geophysics and underground communication are described for illustrative purposes, but many other applications cannot be mentioned for lack of space. The primary purpose of this chapter is to describe how these antennas perform in the presence of a conducting earth.

In order to penetrate the earth to depths on the order of a hundred meters or more, it is necessary to employ extremely low frequencies below about 3 kHz. At such frequencies the free-space wavelength is greater than 100 km, and the antennas are electrically small even though they could be physically large (dimensions on the order of a kilometer in some cases). Consequently, the analyses in Sections 2 through 4 utilize the quasi-static assumption that neglects displacement currents in the air. However, no assumption is made regarding the antenna dimensions and separations in terms of the skin depth in the earth.

In Section 5, some other antenna types are discussed in much less detail. Many of these antennas are used for shorter ranges and higher frequencies where the quasi-static assumption is not valid.
[Contact: David A. Hill, (303) 497-3472]

Kremer, D.P., and Repjar, A.G., **Calibrating Antenna Standards Using CW**

Antenna Metrology (cont'd.)

and Pulsed-CW Measurements and the Planar Near-Field Method, Proceedings of the Antenna Measurement Techniques Association (AMTA), Atlanta, Georgia, September 12-16, 1988, pp. 13-21 to 13-29.

For over a decade, the National Institute of Science and Technology (formerly National Bureau of Standards) has used the planar near-field method to accurately determine the gain, polarization, and patterns of antennas either transmitting or receiving cw signals. Some of these calibrated antennas have also been measured at other facilities to determine and/or verify the accuracies obtainable with their ranges. The facilities involved have included near-field ranges, far-field ranges, and compact ranges.

Recently, NIST (NBS) has calibrated an antenna to be used to evaluate both a near-field range and a compact range. These ranges are to be used to measure an electronically-steerable antenna which transmits only pulsed-cw signals. The antenna calibrated by NIST was chosen to be similar in physical size and frequency of operation to the array and was also calibrated with the antenna transmitting pulsed-cw. This calibration included determining the effects of using different power levels at the mixer, the accuracy of the receiver in making the amplitude and phase measurements, and the effective dynamic range of the receiver. Comparisons were made with calibration results obtained for the antenna transmitting cw and for the antenna receiving cw. The parameters compared include gain, sidelobe and cross polarization levels. The measurements are described and some results are presented.
[Contact: Douglas P. Kremer, (303) 497-3732]

Lewis, R.L., and Newell, A.C., **An Efficient and Accurate Method for Calculating and Representing Power Density in the Near Zone of Microwave Antennas**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 6, pp. 890-901 (June 1988).

An efficient and reliable method has been developed for computing and exhibiting Fresnel-region fields radiated by microwave antennas, using plane-wave scattering-matrix analysis. That is, we calculate near fields by numerically integrating the complex far-field antenna pattern. The predicted near fields are exhibited as relative power-density contours lying in a longitudinal plane bisecting the antenna's aperture. With spatial-coordinate scaling, each set of contours becomes a function of the relative aperture distribution and the electrical size of the antenna. If the latter is much larger than any normalized transverse coordinate of interest, the contour set becomes invariant with respect to antenna size. Thus, coordinate normalization can produce contours applicable to any antenna with the same relative aperture distribution, regardless of antenna size.

The crux of the analysis consists of handling a numerical instability which arises from integrating discrete data. A criterion is developed for excluding highly oscillatory regions of the integrand. In turn, this leads to restrictions on the output range over which the near-field computations are considered valid. With the numerical instability problem resolved, the fast Fourier transform is used for efficient numerical integration. The predicted near fields have been compared against both measured and theoretical data, confirming that our near-field computation algorithm is capable of extremely high accuracy.
[Contact: Richard L. Lewis, (303) 497-5196]

Newell, A.C., **Error Analysis Techniques for Planar Near-Field Measurements**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 6, pp. 754-

Antenna Metrology (cont'd.)

768 (June 1988).

The results of an extensive error analysis on antenna near-field polanar scanning measurements are described. It provides ways for estimating the magnitude of each individual source of error and then combining them to estimate the total uncertainty in the measurement. Mathematical analysis, computer simulation, and measurement tests are all used where appropriate.
[Contact: Allen C. Newell, (303) 497-3743]

Newell, A.C., **Improved Polarization Measurements Using a Modified Three-Antenna Technique**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 6, pp. 852-854 (June 1988).

An improved three-antenna measurement of polarization that greatly reduces the uncertainty due to phase measurement errors is described. This technique is used to calibrate polarization standards and probes used in near-field antenna measurements.
[Contact: Allen C. Newell, (303) 497-3743]

Newell, A.C., and Stubenrauch, C.F., **Effect of Random Errors in Planar Near-Field Measurement**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 6, pp. 769-773 (June 1988).

Expressions are developed which relate the signal-to-noise ratio in the near field to the signal-to-noise ratio in the far field for antenna near-field planar scanning. The expressions are then used to predict errors in far-field patterns obtained from near-field data. A technique is also given to measure the noise in the far-field pattern.
[Contact: Allen C. Newell, (303) 497-3743]

Newell, A.C., Ward, R.D., and McFarlane, E.J., **Gain and Power Parameter Measurements Using Planar Near-Field Techniques**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 6, pp. 792-803 (June 1988).

Equations are developed and measurement techniques described for obtaining gain, effective radiated power, and saturating flux density using antenna near-field planar scanning measurements. These are compared with conventional far-field techniques, and a number of parallels are evident. These give insight to the theory and help to identify the critical measurement parameters. Application of the techniques to the INTELSAT VI satellite are described.
[Contact: Allen C. Newell, (303) 497-3743]

Repjar, A.G., Newell, A.C., and Francis, M.H., **Accurate Determination of Planar Near-Field Correction Parameters for Linearly Polarized Probes**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 6, pp. 855-868 (June 1988).

The receiving patterns of two probes, for both amplitude and phase, must be known and utilized to determine accurately the complete far field of an antenna from near-field measurements. The process of incorporating the probe characteristics in the far-field computation is referred to as "probe correction." When the antenna to be measured is nominally linearly polarized, the measurements are more accurate and efficient if nominally linearly polarized probes are used. Further efficiency is obtained if only one dual-polarized probe is used to allow simultaneous measurements of both components. It should be noted, however, that a single-port probe can be rotated by 90 deg to obtain the second component. A procedure used by the National Institute of Standards and Technology for accurately determining the plane-wave receiving parameters of both single- and dual-port linearly polarized probes is described. Examples are presented and the effect of these probe-receiving characteristics in the

Antenna Metrology (cont'd.)

calculation of the parameters for the antenna being measured under test is demonstrated using appropriate planar near-field theory.
[Contact: Andrew G. Repjar, (303) 497-5703]

Microwave & Millimeter-Wave Metrology

Released for Publication

Holt, D.R., **Scattering Parameters Representing Imperfections in Precision Coaxial Air Lines.**

Scattering parameter expressions are developed for the principal mode of a coaxial air line. The model allows for skin-effect loss and dimensional variations in the inner and outer conductors. Small deviations from conductor circular cross sections are conformally mapped by the Bergman-Kernel Technique. Numerical results are illustrated for a 7-mm air line. An error analysis reveals that the accuracy of the determination of the scattering parameters is primarily dependent on the precision of the measurement of the conductor radii.
[Contact: Donald R. Holt, (303) 497-3574]

Recently Published

Adair, R.T., and Russell, D.H., **A Calibration Service for 30 MHz Attenuation and Phase Shift,** NBS Special Publication 250-32 (April 1988).

A calibration service currently being offered by NIST (formerly NBS) for attenuation and phase shift at 30 MHz is described. The service offers measurements on coaxial attenuators that are either fixed (standard attenuation) or variable for incremental (step) attenuation. Waveguide-below-cutoff variable attenuators with coaxial connectors are also calibrated for incremental attenuation. Ranges of capabilities and estimated limits of systematic and random uncertainty are presented.

Calibration of phase shifters which provide fixed (insertion) phase shift and those with variable phase shift (phase shift difference) are described. Ranges of phase shift and estimated limits of uncertainty are given in degrees. However, a smaller portion of this document is devoted to this calibration service since it is requested only infrequently.

Definitions, capabilities of the system, and techniques of calibration are given. The standards, measurement accuracies, results from intercomparisons, quality assurance, and statistical control of the system are discussed and analyzed. Representative reports of calibration are also included.
[Contact: Daved H. Russell, (303) 497-3148]

Counas, G.J., and Yates, B.C., **Measurement of Adapter Loss, Mismatch, and Efficiency Using the Dual Six-Port,** NBSIR 88-3096 (July 1988).

A noise measurement system is being developed for the Air Force which uses coaxial cryogenic and ambient noise temperature standards to determine the noise temperature of the device under test. When the device under test has a different connector than those on the noise standards, an adapter has to be used. Adapter loss and complex reflection coefficient must be compensated for, or noise measurement accuracy is affected. A technique has been developed which uses a dual six-port measurement system to determine the mismatch, loss, and ultimately the efficiency of the adapter used. This enables correction of measurement results and allows measurements to be made with an adapter with no degradation of accuracy. The method of evaluating adapters is described, and instructions for its use are provided.
[Contact: George J. Counas, (303) 497-3664]

Optical Fiber Metrology

Released for Publication

Danielson, B.L., and Whittenberg, C.D., **Group Index and Time Delay Measurements of a Standard Reference Fiber**, to be published as NISTIR 88-3091.

We describe measurement techniques for establishing a standard reference fiber with a well-characterized group index and time or group delay. Evaluation of an interferometric method indicates that fiber group index can be determined with a total estimated uncertainty of about 0.03% in small samples. Group delay of the reference fiber was measured with an overall uncertainty less than 0.004% in a 7-km waveguide. We discuss the application of a standard reference fiber to calibration of the distance measurement accuracy of an optical time-domain reflectometer.
[Contact: Bruce L. Danielson, (303) 497-5620]

Day, G.W., and Franzen, D.L., **Technical Digest, Symposium on Optical Fiber Measurements, 1988**, to be published as an NIST Special Publication.

This digest contains summaries of all of the papers given at the fifth biennial Symposium on Optical Fiber Measurements, held September 20-21, 1988, at the National Institute of Standards and Technology, Boulder, Colorado.

The organizers comment: As always, certain themes appear in the program. This year, we see the largest ever group of papers on optical time domain reflectometry (OTDR), apparently motivated in large part by concern about reflections and their effects on source behavior. The second largest group of papers concerns the measurement of cut-off wavelength. And for the first time, we see a significant number of papers on the characterization of planar optical waveguides.

The Symposium continues to enjoy broad international support. This year's program includes participants from 25 organizations in 8 countries; more than 40% of the papers are from outside the United States."
[Contact: Gordon W. Day, (303) 497-5204]

Franzen, D.L., **Optical Fiber Measurements: Results of Interlaboratory Evaluations.**

Because of the multivendor marketplace, there are often several measurement methods in simultaneous use for determining the same fiber parameter. Results of industry-wide round-robin comparisons administered by the National Institute of Science and Technology (formerly National Bureau of Standards) and the Electronic Industries Association are presented.
[Contact: Douglas L. Franzen, (303) 497-3346]

Sun, Z., and Gallawa, R.L., **The Accuracy of Determining β from Empirical Relations for the Eigenvalue Parameter for Optical Fibers.**

We examine the accuracy that one can expect in finding the propagation constant β for waveguides of various cross-sectional shapes when using recently derived empirical equations for the eigenvalue U.
[Contact: Robert L. Gallawa, (303) 497-3761]

Recently Published

Scace, R.I., **Optical Communication**, ASTM Standardization News, pp. 30-32 (Sept. 1988).

A new communication medium with exciting capabilities is being put into service around the world. It exploits the astonishing transparency to infrared light of high purity silica (fused quartz) fibers to carry extremely high quantities of information long distances at low cost. Much has been made of

Optical Fiber Metrology (cont'd.)

optical fibers in advertising telephone services, but these ads deal with only the beginning of a communication revolution.
[Contact: Robert I. Scace, (301) 975-2220]

Electro-Optic Metrology

Released for Publication

Day, G.W., and Rose, A.H., **Faraday Effect Sensors: The State of the Art,** to be published in the SPIE Proceedings, Vol. 985, Fiber Optics and Laser Sensors VI, September 6-7, 1988.

The Faraday effect is becoming widely used as an optical method of measuring electric current or magnetic field. It is particularly advantageous where the measurements must be made at high voltage or in the presence of electromagnetic interference, and where speed or stability are considerations. In this paper we review the development of the technology over the last twenty years, with an emphasis on the basic principles, design considerations, and performance capabilities of sensors that represent the latest achievements. Faraday effect current sensors are now used routinely in the measurement of large current pulses, and are starting to become available for ac current measurements in the power industry. Recent developments include their extension to the measurement of currents in the milliampere range and substantial reductions in size. Similar devices, in slightly different configurations, can be used for magnetic field measurements. Further improvements, based on new fiber types and new materials, are projected.
[Contact: Gordon W. Day, (303) 497-5204]

Other Fast Signal Topics

Released for Publication

Bennett, H.E., Guenther, A.H., Milan, D., and Newnam, B.E., **Laser Induced Damage in Optical Materials: 1986**, to be published as an NIST Special Publication.

The Eighteenth Annual Symposium on Optical Materials for High Power Lasers (Boulder Damage Symposium) was held at the National Bureau of Standards (now the National Institute of Standards and Technology) in Boulder, Colorado, November 3-5, 1986. The Symposium was held under the auspices of ASTM Committee F-1, Subcommittee on Laser Standards, with the joint sponsorship of NIST, the Defense Advanced Research Project Agency, the Department of Energy, the Office of Naval Research, and the Air Force Office of Scientific Research. Approximately 200 scientists attended the Symposium, including representatives from the United States, the United Kingdom, Japan, France, and the Federal Republic of Germany. The Symposium was divided into sessions concerning Materials and Measurements, Mirrors and Surfaces, Thin Films, and Fundamental Mechanisms. As in previous years, the emphasis of the papers presented at the Symposium was directed toward new frontiers and new developments. Particular emphasis was given to materials for high-power apparatus. The wavelength range of the prime interest was from 10.6 μm to the ultraviolet. Highlights include surface characterization, thin film-substrate boundaries, and advances in fundamental laser-matter threshold interactions and mechanisms. Harold E. Bennett of the Naval Weapons Center, Arthur H. Guenther of the Air Force Weapons Laboratory, David Milam of the Lawrence Livermore National Laboratory, and Brian E. Newnam of the Los Alamos National Laboratory were co-chairmen of the Symposium.
[Contact: Aaron A. Sanders, (303) 497-5341]

Young, M., **Imaging Without Lenses or Mirrors: The Pinhole Camera and Its Relatives.**

The pinhole camera is an interesting and

Other Fast Signal Topics (cont'd.)

useful device. The pinhole focuses as a result of diffraction, and the camera displays an optimum focal length equal to the square of the pinhole radius divided by the wavelength. This paper discusses the history and the physics of the pinhole camera and some of its relatives, the Fresnel zone plate, cascaded apertures, the pinspeck camera, and the pinhead mirror.
[Contact: Matt Young, (303) 497-3223]

Recently Published

Capobianco, T.E., and Vecchia, D.F., **Coil Parameter Influence on Eddy Current Probe Sensitivity**, Review of Progress in Quantitative Nondestructive Evaluation, Vol. 7A, D.O. Thompson and D.E. Chimenti, Eds. (Plenum Publishing Corporation, 1988), pp. 487-492.

Results of a study undertaken to quantify causes of sensitivity variations found in commercial eddy current probes are reported. Electrical parameter measurements made on a number of commercially produced coils indicate that coil reproducibility is not a major problem in the probe construction process. On the other hand, commercial probes designed for a particular inspection can have sensitivities differing by almost an order of magnitude. It appears that while individual probe manufacturers can produce many identical probes, the choice of coil design parameters can lead to flaw-detectability variations in eddy current probes obtained from different sources.

This study evaluates the effects on sensitivity of changes in the physical parameters of small ferrite core coils. Among the parameters studied were wire gauge, number of wire turns, coil aspect ration, ferrite permeability, and operating frequency. The criteria used to gauge probe sensitivity are the impedance changes observed on applying the coils to four semi-elliptical electrical-discharged-machined notches in aluminum and to aluminum and titanium test blocks. The results indicate that coils with similar electrical characteristics but different physical parameters can have significant differences in sensitivity.
[Contact: Thomas E. Capobianco, (303) 497-3141]

Fickett, F.R., and Capobianco, T.E., **Conductors for Advanced Energy Systems**, Conductors for Advanced Energy Systems Annual Report, INCRA Project #321B (International Cooper Research Association, Inc., New York, NY, October 1987).

In this report we present the results of extensive mechanical-properties tests on a large number of oxygen-free copper samples representing a range of producers and wire tempers. Tests at both room temperature and liquid-helium temperature (4 K) are reported. A specialized apparatus developed for the low-temperature tests is described. Results of the many tests are presented in graphical and tabular form. The most interesting of the results is that it appears possible to predict the strength of oxygen-free copper wires at low temperatures by the measurement of the residual resistance ratio (RRR), the ratio of the room temperature resistance to that measured at 4 K. This result is of great importance in applications, since many laboratories are able to measure RRR, but few can do low-temperature mechanical properties tests.
[Contact: Fred Fickett, (303) 497-3785]

Hill, D.A., **Electromagnetic Scattering by Buried Objects of Low Contrast**, IEEE Transactions on Geoscience and Remote Sensing, Vol. 26, No. 2, pp. 195-203 (March 1988).

The Born approximation is used to derive the plane-wave scattering matrix for objects of low dielectric contrast. For general shapes, a numerical integration over the volume of the scatterer is required, but analytical expressions are

Other Fast Signal Topics (cont'd.)

derived for a sphere, a circular cylinder, and a rectangular box (parallelepiped). Plane-wave, scattering-matrix theory is used to account for the air-earth interface. Numerical results are presented for the scattered near field and far field for plane-wave excitation. The scattered fields are weak for low-contrast objects, but the near-field results have application to electromagnetic detection of buried objects.
[Contact: David A. Hill, (303) 497-3472]

ELECTRICAL SYSTEMS

Power Systems Metrology

Released for Publication

Martzloff, F.D., **Power Quality Standards,** to be published in the Proceedings of the Power Electronic Applications Center Conference, Knoxville, Tennessee, October 25, 1987.

The issue of power quality has recently become more pressing as more sensitive load equipment is being installed by all end-users of electric power. The issue has also become more pressing because some of the new load equipment circuits create disturbance within the end-user system. Mechanisms leading to poor quality in the power supply are well known among power system engineers, but new concerned parties are emerging as applications of the new equipment introduce these newcomers to the old problems. This increasing awareness can take the form of adversarial relations between power supplier (the electric utilities) and power user (the end-users: industry, commerce, and consumer). These adversarial positions are in part rooted in incomplete knowledge of the mechanisms of disturbances and of the facts concerning their mitigation. In some instances, subjective reactions creep into the process of dealing with a technical problem. Standards addressing these concerns can provide the necessary degree of objectivity and reconcile adversaries by developing a consensus based on reliable, safe, and cost-effective solutions.
[Contact: Francois D. Martzloff, (301) 975-2409]

McKenny, P.J., Forster, E.O., Kelley, E.F., and Hebner, R.E., **Effect of Pressure on the Development of Prebreakdown Streamers--Collapse and Reversal,** to be published in the Proceedings of the Conference on Electrical Insulation and Dielectric Phenomena, Ottawa, Canada, October 17-20, 1988.

The initiation of streamers in a liquid under the application of impulse voltages applied to a needle-sphere gap was investigated. A square pulse was applied having a peak voltage so that the streamer would not grow to breakdown before the pulse was chopped to zero. With the application of pressure, the initial streamer was observed to collapse and disappear while the voltage remained on the tip. When the voltage was chopped, a new streamer appeared which resembled the structure of the anode streamers, the branches of which did not strictly follow the previous branches of the cathode tree which injected the charge in the liquid. Using a simple model, approximately 11 nC is estimated to be injected into the liquid for a charge density of 49 $\mu C/cm^3$.
[Contact: Edward F. Kelley, (301) 975-5826]

Misakian, M., **AC Electric and Magnetic Field Meter Fundamentals,** to be published in the Proceedings of the EPRI Utility Seminar on Power Frequency and Magnetic Field Exposure Assessment, Colorado Springs, Colorado, October 12-14, 1988.

Questions raised in the early 1970s regarding possible adverse environmental effects due to high-voltage ac trans-

Power Systems Metrology (cont'd.)

mission line fields focused attention on the need for accurate measurements of the power-frequency electric and magnetic fields. Following a brief description of the fields near ac power lines, this paper surveys the instrumentation, calibration procedures, measurement techniques and standards that have been developed since the early 1970s to characterize the electric and magnetic fields near ac power lines.
[Contact: Martin Misakian, (301) 975-2426]

Misakian, M., **Discussion of Paper 88 SM 560-5, Performance of a Long-Term Unattended Station for Measuring DC Fields and Air Ions from an Operating HVDC Line.**

This discussion refers to a paper presented at the IEEE Power Engineering Society 1988 summer meeting in Portland, OR.
[Contact: Martin Misakian, (301) 975-2426]

Van Brunt, R.J., **Processes Leading to SF_6 Decomposition in Glow-Type Corona Discharges**, to be published in the Proceedings of the 14th Summer School and International Symposium on the Physics of Ionized Gases, Sarajevo, Yugoslavia, August 15-19, 1988.

Recent progress which has been made in understanding the fundamental gas-phase oxidation processes involving SF_6 in corona discharges is discussed here within the framework of a three-zone chemical kinetics model. Gaps in our knowledge about fundamental molecular interactions that are keys to a better understanding of SF_6 oxidation are discussed.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Recently Published

Anderson, W.E., **A Calibration Service for Voltage Transformers and High-Voltage Capacitors**, NBS Special Publication 250-33 (June 1988).

The National Institute of Standards and Technology calibration service for voltage transformers and high-voltage capacitors is described. The service for voltage transformers supports the measurement of ratio correction factors and phase angles at primary voltages up to 170 kV and secondary voltages as low as 10 V at 60 Hz. Calibrations at frequencies from 50 to 400 Hz are available over a more limited voltage range. The service for high-voltage capacitors supports the measurement of capacitances and dissipation factors at applied voltages ranging from 100 V to 170 kV at 60 Hz depending on the nominal capacitance. Calibrations over a reduced voltage range at other frequencies are also available. As in the case with voltage transformers, these voltage constraints are determined by the facilities at the National Institute of Standards and Technology.
[Contact: William E. Anderson, (301) 975-2423]

Moore, W.J.M., So, E., Miljanic, P.N., Oldham, N.M., and Bergeest, R., **An International Comparison of Power Meter Calibrations Conducted in 1987**, Conference Digest of CPEM'88, 1988 Conference on Precision Electromagnetic Measurements, Tsukuba Science City, Japan, June 7-10, 1988, pp. 341-342 (IEEE, New York, New York, June 1988).

The results of an intercomparison of power meter calibrations conducted during 1987 between the National Research Council, Ottawa (Canada), the National Bureau of Standards, Gaithersburg (U.S.A.), and the Physikallsch-Technische Bundesanstalt, Braunschweig (Federal Republic of Germany), using a time-division multiplier watt-converter developed at the Institut Mihailo Pupin, Belgrade (Yugoslavia), are described. The measurements were made at 120 V, 5 A, 50 and 60 Hz, at power factors of 1.0, 0.5 lead and lag, and 0.0 lead and lag. An agreement between laboratories

Power Systems Metrology (cont'd.)

of better than 20 parts in a million is indicated.
[Contact: Nile H. Oldham, (301) 975-2408]

Olthoff, J.K., Van Brunt, R.J., Wang, Y., Champion, R.L., and Doverspike, L.D., **Collisional Electron Detachment Cross Sections for SF_6^-, SF_5^-, and F^- in SF_6: Implication for Interpretations of Existing Ion Transport and Breakdown Probability Data**, Proceedings of IX International Conference on Gas Discharges and Their Applications, Venice, Italy, September 19-23, 1988, pp. 363-366 (Bennetton Editore, Padova, Italy, 1988).

Collisional electron-detachment cross sections for SF_6^-, SF_5^-, and F^- on SF_6 target gas have been measured for relative (center-of-mass) energies in the range of 3 to 250 eV. Apparent thresholds for direct detachment are observed at 90 eV for SF_6^- and SF_5^-, and at 8 eV for F^-. Cross sections for ion-conversion processes that compete with detachment are reported and indicate the necessity to re-examine ion-conversion rates determined in SF_6 from drift-tube data. The measured cross sections are used in a theoretical model which invokes detachment from long-lived, energetically unstable states of collisionally excited SF_6^- to explain the pressure dependence of previously measured detachment coefficients and the high detachment thresholds implied by analysis of breakdown-probability data for SF_6. The model indicates that at high pressure, measured detachment coefficients appear to depend primarily upon ion-conversion and direct detachment rates for processes involving F^-.
[Contact: James K. Olthoff, (301) 975-2427]

Van Brunt, R.J., and Kulkarni, S.V., **Stochastic Properties of Negative Corona (Trichel) Pulses in SF_6/O_2 Mixtures**, Proceedings of the 9th International Conference on Gas Discharges and Their Applications, Venice, Italy, September 19-23, 1988, pp. 227-230 (Bennetton Editore, Padova, Italy, 1988).

The statistical probability distributions of discharge pulse amplitude, $p_o(q)$, pulse time interval, $p_o(\Delta t)$, and pulse amplitude for a given time separation, Δt, from the previous pulse, $p_1(q|\Delta t)$ have been measured for Trichel-type negative point-plane corona in SF_6/O_2 gas mixtures as functions of point-to-plane voltage and mixture ratio. The results reveal significant, previously unrecognized correlations among the amplitudes and time intervals of successive discharge pulses which are consistent current theoretical descriptions of the phenomenon. As the SF_6 content in SF_6/O_2 mixtures is increased, the growth of negative corona pulses diminishes as reflected in lower mean pulse amplitudes and the pulses appear more randomly in time; i.e., there is a broadening of the pulse time-interval distributions.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Van Brunt, R.J., and Siddagangappa, M.C., **Identification of Corona Discharge-Induced SF_6 Oxidation Mechanisms Using SF_6-$^{18}O_2$-$H_2{}^{16}O$ and SF_6-$^{16}O_2$-$H_2{}^{18}O$ Gas Mixtures**, Plasma Chemistry and Plasma Processing, Vol. 8, No. 2, pp. 207-223 (Plenum Publishing Corporation, June 1988).

The absolute yields of gaseous oxyfluorides SOF_2, SO_2F_2, SOF_4, from negative, point-plane corona discharges in pressurized gas mixtures of SF_6 with O_2 and H_2O enriched with $^{18}O_2$ and $H_2{}^{18}O$ have been measured using a gas chromatograph-mass spectrometer. The predominant SF_6 oxidation mechanisms have been revealed from a determination of the relative ^{18}O and ^{16}O isotope content of the observed oxyfluoride by-products. The results are consistent with previously proposed production mechanisms and indicate that SOF_2 and SO_2F_2 derive oxygen predominantly from H_2O and O_2, respectively, in

Power Systems Metrology (cont'd.)

slow, gas-phase reactions involving SF_4, SF_3, and SF_2 that occur outside of the discharge region. The species SOF_4 derives oxygen from both H_2O and O_2 through fast reactions in the active discharge region involving free radicals or ions such as HO and O, with SF_5 and SF_4.
[Contact: Richard J. Van Brunt (301) 975-2425]

Van Brunt, R.J., Sieck, L.W., Sauers, I., and Siddagangappa, M.C., **Transfer of F^- in the Reaction of SF_6^- with SOF_4: Implications for SOF_4 Production in Corona Discharges** [original title: Transfer of F^- in SF_6^- + SOF_4 Collisions and Its Influence on SOF_4 Yield from Corona Discharges in Gases Containing SF_6], Plasma Chemistry and Plasma Processing, Vol. 8, No. 2, pp. 225-246 (Plenum Publishing Corporation, June 1988).

The temperature (T) and electric field-to-gas pressure (E/P) dependences of the rate constant k for the reaction $SF_6^- + SOF_4 \rightarrow SOF_5^- + SF_5$ have been measured. For $T < 270$ K, k approaches a constant of 2.1×10^{-9} cm^3/s, and for $433 K > T > 270$ K, k decreases with T according to $k(cm^3/s) = 0.124 \exp(-3.3 \ln T(k))$. For $E/P < 60$ V/cm·torr, k has a constant value of about 2.5×10^{-10} cm^3/s, and for 130 V/cm·torr, the rate is approximately given by $k(cm^3/s) \approx 7.0 \times 10^{-10} \exp(-0.022 E/P)$. This reaction is shown to be important in controlling the yield of SOF_4 from corona discharges in gas mixtures containing SF_4 amd at least trace amounts of O_2 and H_2O. The observed behavior of SOF_4 production rates for negative, point-plane corona discharges is analyzed using k in a chemical kinetics model of the ion-drift region in the discharge gap, and it is shown that competing reactions not involving SOF_4 are effective in deactivating SF_6^-.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Superconductors

Released for Publication

Bray, S.L., and Ekin, J.W., **Effect of Room Temperature Stress on the Critical Current of NbTi.**

Superconducting composites which are used in the construction of large-scale magnets may be subjected to several sources of mechanical stress. These stresses occur within three different temperature regimes: room temperature, the transition between room and liquid-helium temperatures, and at liquid-helium temperature (≈4 K). Until now, only critical-current degradation from stresses introduced at liquid-helium temperature have been measured. This paper presents the results of the first measurements of the effect on critical current of tensile stress applied at room temperature. The results indicate a simple general relationship, namely, that the stress effect on critical current of NbTi is independent of the temperature at which the stress is applied. This result may be of considerable benefit to the magnet designers since the existing data base of helium-temperature stress effects in NbTi is directly applicable to tensile stresses introduced at room temperature during magnet fabrication. The results should be particularly useful in setting stress limits in large magnet applications where the combined fabrication and Lorentz forces are great.
[Contact: Steven Bray, (303) 497-5631]

DeWeese, M.E., Kamper, R.A., and Powell, R.M., **High-Temperature Superconductivity: Abstracts of NIST Publications, 1987-1988,** to be published as an NIST Special Publication.

We have collected abstracts from 61 papers published between March 1987 and May 1988 covering various aspects of superconductivity research. The work of nine divisions of the National Institute of Standards and Technology (formerly the National Bureau of Standards) in

Superconductors (cont'd.)

both Boulder, Colorado, and Gaithersburg, Maryland, is represented.
[Contact: M. Edie DeWeese, (303) 497-5700]

Goodrich, L.F., and Bray, S.L., **Critical-Current Measurements of Nb_3Sn Superconductors: NIST Contribution to the VAMAS Round Robin.**

Critical-current measurements on several NB_3Sn superconductors were made. These were round-robin measurements (interlaboratory comparison) made in conjunction with twenty-five laboratories from the European Economic Community, Japan, and the USA as part of the Versailles Agreement on Advanced Materials and Standards (VAMAS). The results of the NIST measurements, including the effect of sample mounting techniques on the measured critical current, are given. A systematic study of the effect of measurement mandrel (tubular sample holder made from G-10 fiberglass-epoxy composite) geometry revealed that a seemingly small change in that geometry can result in a 40% change in the measured critical current at a magnetic field of 12 T. Specifically, the radial thermal contraction of the measurement mandrel depends on its wall thickness and, thus, so do the conductor prestrain (at 4 K) and, ultimately, the measured critical current. Techniques for reducing this and other measurement variables are suggested.
[Contact: Loren F. Goodrich, (303) 497-3143]

Goodrich, L.F., and Bray, S.L., **Current Capacity Degradation in Superconducting Cable Strands.**

The electromagnetic properties of NbTi strands extracted from Rutherford-type cables were studied to clarify the effect of mechanical deformation, caused by the cabling process, on the current capacity of the strands. Three different cables were studied, all of which are prototypes for the Superconducting Super Collider's dipole magnets. The extended cable strands were instrumented to allow measurement of the voltage across several key regions of mechanical deformation as a function of current and the orientation of the applied magnetic field. The resulting data are presented in terms of the strands' voltage profile as well as its critical current to more thoroughly characterize the conductors' electromagnetic properties. The cable strands show very localized reductions in current capacity that are well correlated with the regions of high mechanical deformation. For example, at a particular field orientation, the voltage across a portion of the strand that is only 3% of the total strand length contributes 92% of the total strand voltage. Two applied magnetic field orientations, parallel and perpendicular to the cable's width, are shown to have pronounced effects on the electrical properties of the strand. Both of these magnetic field orientations will arise in application.
[Contact: Loren F. Goodrich, (303) 497-3143]

Goodrich, L.F., Bray, S.L., and Stauffer, T.C., **Nb_3Sn Critical Current Measurements on Tubular Fiberglass-Epoxy Mandrels.**

A systematic study of the effect of sample mounting techniques on the superconducting critical-current measurement was made in conjunction with the VAMAS (Versailles Agreement on Advanced Materials and Standards) round-robin measurements. A seemingly small change in mandrel geometry can result in a 40% change in the measured critical current of a Nb_3Sn sample at 12 T. This is a result of a change in the conductor pre-strain (at 4 K) due to variation in thermal contraction between thick- and thin-walled fiberglass-epoxy composite (G-10) tubes. An approximate measure of the thermal contraction (from room to liquid nitrogen temperature) variations indicate a 0.2% greater contraction for the thick-wall tube. This difference

Superconductors (cont'd.)

combined with strain sensitivity measurements is consistent with the observed decrease in critical current. Previous publications on the thermal contraction of G-10 have addressed the plate geometry but not the tube geometry. The contraction of a G-10 plate is highly anisotropic. However, the radial contraction of a tube is different than the contraction of a plate because the circumferential fiberglass is put in hoop compression by the epoxy and the resulting contraction is a competition between the two structural components. This appears to be the source of the thermal contraction variation with tube wall thickness.
[Contact: Loren F. Goodrich, (303) 497-3143]

Moreland, J., and Goodrich, L.F., **Ag Screen Contacts to Sintered YBa_2 Cu_3 O_x Powder for Rapid Superconductor Characterization**, to be published in the Proceedings of the Applied Superconductivity Conference, San Francisco, California, August 21-25, 1988.

We have developed a new method for making current contacts and voltage taps to YBa_2 Cu_3 O_x sintered pellets for rapid superconductor characterization. Ag wire screens are interleaved between calcined powder sections and then fired at 930°C to form a composite pellet for resistivity and critical current measurements. The Ag diffuses into the powder during the sintering process, forming a proximity contact that is permeable to oxygen. Contact surface resistivities (area-resistance product) range from 1 to 10 $\mu\Omega \cdot cm^2$ at 77 K for the Ag-powder interface. In this configuration, current can be uniformly injected into the ends of the pellet through the bonded Ag screen electrodes. Also, Ag screen voltage contacts which span a cross section of the pellet may provide an ideal geometry for detecting voltage drops along the pellet, minimizing current transfer effects.
[Contact: John Moreland, (303) 497-3641]

Moreland, J., Li, Y., Folsom, R.M., and Capobianco, T.E., **Novel "Bathysphere" Cryostat for Resistance Versus Temperature Experiments on High-T_c Superconductors**, to be published in the Proceedings of the Applied Superconductivity Conference, San Francisco, California, August 21-25, 1988.

We have developed a novel cryostat for variable temperature testing of high-temperature superconductors. The cryostat is a bathysphere consisting of an overturned stainless-steel Dewar flask suspended in liquid helium. A sample-heater-thermometer assembly is located at the top of the encapsulated (and thermally insulated) vapor space inside of the Dewar. The sample can be rapidly cycled from 300 K to 4 K at an average rate of 1 K/min with a thermal hysteresis of less than 0.1 K. Helium vapor flows through a plug in the bottom of the bathysphere so that pressure of the vapor is roughly ambient. This provides ample heat transfer to and from the sample to maintain thermal equilibrium in the vapor space. Results for resistance-versus-temperature of some high-temperature superconductors in a magnetic field are presented. Also, various definitions for thermodynamic and practical critical temperatures derived from transport resistivity measurements are suggested and discussed.
[Contact: John Moreland, (303) 497-3641]

Tachikawa, K., Itoh, K., Wada, H., Gould, D., Jones, H., Walters, C.R., Goodrich, L.F., Ekin, J.W., and Bray, S.L., **VAMAS Intercomparison of Critical Current Measurement in Nb_3Sn Wires.**

The VAMAS (Versailles Agreement on Advanced Materials and Standards) technical working party in the area of superconducting and cryogenic structural materials has recently carried out the first world-wide intercomparison of

Superconductors (cont'd.)

critical current, I_c, measurement on multifilamentary Nb_3Sn wires. Three sample wires each were supplied by the European Community, Japan, and USA. The total number of participant labs was 25 (European Community 12, Japan 8, and USA 5). There were few restrictions for the I_c measurement at participant labs. The standard deviations of the I_c values reported from these labs varied from 6 to 20% at 12 tesla. Possible reasons of the I_c deviation among labs are discussed.
[Contact: Loren F. Goodrich, (303) 497-3143]

Recently Published

Ekin, J.W., **Relationships Between Critical Current and Stress in NbTi** [original title: Critical Current vs Stress Relationships in NbTi Superconductors], IEEE Transactions on Magnetics, Vol. MAG-23, No. 2, pp. 1634-1637 (March 1987).

The effects of various types of stress on the critical current of a multifilamentary NbTi superconductor are reported. Degradation of critical current due to axial tension applied at 4 K, transverse compression applied at 4 K, and hairpin bending strain applied at room temperature has been measured. The degradation from axial tension is much greater than from transverse compression in many practical cases because the soft copper matrix limits the buildup of transverse compression. The degradation from typical levels of transverse compression is only about 4% at 8 T, for example. For axial tension, on the other hand, higher stresses can occur that will degrade the critical current by 24%, for example, at 7 T and 2.7% strain. Both the axial-tensile and the transverse-compressive stress effects are about 98% reversible; thus the degradation will be seen only when the conductor is under operational stress. The results indicate that a primary origin of the critical current degradation in NbTi is a stress-induced reversible decrease in the upper critical field.
[Contact: John W. Ekin, (303) 497-5448]

Ekin, J.W., Larson, T.M., Bergren, N.F., Nelson, A.J., Swartzlander, A.B., Kazmerski, L.L., Panson, A.J., and Blankenship, B.A., **High T_c Superconductor/Noble-Metal Contacts with Surface Resistivities in the 10^{-10} $\Omega \cdot cm^2$ Range**, Applied Physics Letters, Vol. 52, No. 21, pp. 1819-1821 (May 23, 1988).

Contact surface resistivities (product of contact resistance and area) in the 10^{-10} $\Omega \cdot cm^2$ range have been obtained for both silver and gold contacts to high-T_c superconductors. This is a reduction by about eight orders of magnitude from the contact resistivity of indium-solder connections, low enough to be considered for interconnect applications. The contacts were formed by sputter depositing either silver or gold at low temperatures (<100°C) on a clean surface of $Y_1Ba_2Cu_3O_{7-\delta}$ (YBCO) and later annealing the contacts in oxygen. Annealing temperature characteristics show that for bulk-sintered YBCO samples, there is a sharp decrease in contact resistivity after annealing silver/YBCO contacts in oxygen for 1 h at temperatures above ~500°C and gold/YBCO contacts for 1 h above ~600°C. Oxygen annealing for longer times (8 h) did not reduce the contact resistivity of silver contacts as much as annealing for 1 h. Auger microprobe analysis shows that indium/YBCO contacts contain a significant concentration of oxygen in the indium layer adjacent to the YBCO interface. Silver and gold contacts, on the other hand, contain almost no oxygen and have favorable interfacial chemistry with low oxygen affinity. Silver also acts as a "switchable" passivation buffer, allowing oxygen to penetrate to the YBCO interface at elevated temperatures, but protecting the YBCO surface at room temperature.
[Contact: John W. Ekin, (303) 497-5448]

Superconductors (cont'd.)

Kamper, R.A., and Clark, A.F., **Superconductivity: Challenge for the Future**, Journal of Research of the National Bureau of Standards, Vol. 92, No. 6, pp. 391-392 (November-December 1987).

This is a brief report on the Federal Conference on Commercial Applications of Superconductivity, Washington, DC, July 28-29, 1987.
[Contact: Robert A. Kamper, (303), 497-3535]

Moreland, J., Beall, J.A., Ono, R.H., and Clark, A.F., **Recent Tunneling Measurements of 90 K Superconductors at NBS**, Proceedings of Materials Research Society Spring Meeting, Symposium K, High-T_c Superconductors, Reno, Nevada, April 5-9, 1988, (Materials Research Society, Pittsburgh, Pennsylvania, 1988), pp. 351-353.

Several tunneling measurements on oxide superconductors have been made at NBS in the last year. These include break junction tunneling measurements of the energy gap, break junction superconducting point contacts, and the operation of a break junction point contact radio-frequency superconducting quantum interference device (SQUID) above 77 K. Until recently, these tunneling experiments have been limited to bulk samples cut from sintered pellets and a few small single crystals. We present here further results on thin films of $YBa_2Cu_3O_x$ (YBCO) using squeezable electron tunneling (SET) junctions. In contrast to the break junction tunneling experiments on bulk samples, where quite often tunneling spectra are without energy gap features, the spectra for thin-film SET junctions are rich with structure.
[Contact: John Moreland, (303) 497-3641]

Moreland, J., Clark, A.F., Damento, M.A., and Gschneider, K.A., Jr., **Single Crystal $HoBa_2Cu_3O_x$ Break Junctions**, Physics C, Proceedings of the International Conference on High Temperature Superconductors - Materials and Mechanisms of Superconductivity, Interlaken, Switzerland, February 29-March 4, 1988 (North-Holland Physics Publishing Division, North-Holland, Amsterdam, 1988), pp. 1383-1384.

Tunneling spectra of $HoBa_2Cu_3O_x$ single crystals using the break junction method show energy gap features. These features are variable from junction to junction possibly due to an anisotropic gap function. The I-V curves show the peculiar square law dependence of the current on voltage seen in many tunneling measurements of polycrystalline samples of 90-K superconductors. This may be an indication of an inherent "granularity" built into the superconducting matrix of a single crystal.
[Contact: John Moreland, (303) 497-3641]

Moreland, J., Goodrich, L.F., Ekin, J.W., Capobianco, T.E., and Clark, A.F., **Break Junctions I**, NBSIR 88-3090 (May 1988).

Measurements of the tunneling current-voltage characteristics of break junctions in conventional superconductors can be used to determine their superconducting energy gap as a function of energy. These results agree with those previously obtained using traditional oxide tunneling barriers. Break junctions in some exotic superconductors, on the other hand, have anomalous current-voltage characteristics compared to BCS theory predictions. Energy gaps and the Josephson effect measurement for the new high T_c materials YBaCuO (T_c = 93 K) and LaSrCuO (T_c = 36 K) indicate that the samples are inhomogeneous with varying gap functions depending on the location of the tunneling contact within the break junction fracture. Break junction data for these materials are within the strong coupling limits of BCS theory.
[Contact: John Moreland, (303) 497-3641]

ELECTROMAGNETIC INTERFERENCE

Radiated Electromagnetic Interference

Released for Publication

Ma, M.T., **How High is the Level of Electromagnetic Fields Radiated by an ESD?**, to be published in the Proceedings of the 8th Symposium & Technical Exhibition on EMC, Switzerland, March, 1989.

Quantitative estimation of the electromagnetic fields radiated by electrostatic discharges (ESD) is of importance to the users and to the computer industry. Analytical and experimental results, based on a new theoretical model and specific measurement system, are presented.
[Contact: Mark T. Ma, (303) 497-3800]

Recently Published

Crawford, M.L., and Ladbury, J.M., **Mode-Stirred Chamber for Measuring Shielding Effectiveness of Cables and Connectors, An Assessment of MIL-STD-1344A Method 3008**, Proceedings of the 1988 IEEE International Symposium on Electromagnetic Compatibility, Seattle, Washington, August 2-4, 1988, pp. 30-36 (1988).

The mode-stirred method for measuring the shielding effectiveness (SE) of cables and connectors as specified in MIL-STD-1344A Method 3008 is examined. Problems encountered in applying the method are identified and recommendations are provided to improve the measurement results. These include chamber design, type and placement of transmitting and reference receiving antenna, determination and correction for VSWR of the reference antenna and equipment under test, and the measurement approach to use at specified test frequencies. Design and measurement setups for a small mode-stirred chamber suitable for performing SE measurements in the frequency range from 1 to 18 GHz with dynamic ranges up to 130 dB are given along with SE measurement results of some sample equipment.
[Contact: Myron L. Crawford, (303) 497-5497]

Ma, M.T., **Understanding Reverberating Chambers as an Alternative Facility for EMC Testing**, Journal of Electromagnetic Waves and Applications, Vol. 2, Nos. 3/4, pp. 339-351 (1988).

A relatively new facility called a reverberating chamber designed for electromagnetic compatibility (EMC) testing is described. The purpose is to create a statistically uniform electric field inside a metal enclosure for testing radiated susceptibility or immunity of equipment. Design criteria in terms of the number of cavity modes, mode density, and composite quality factor are presented in detail in order to understand the physical insight and to enhance interpretations of measurement results. Recent experimental data are included to illustrate the underlying principle.
[Contact: Mark T. Ma, (303) 497-3800]

Wilson, P.F., Ondrejka, A.R., and Ma, M.T., **Fields Radiated by Electrostatic Discharges**, Proceedings of the IEEE International Symposium on Electromagnetic Compatibility, Seattle, Washington, August 2-4, 1988, pp. 179-183 (1988).

Electrostatic discharge (ESD) can be a serious threat to electronic equipment. To date, metrology efforts have focused primarily on ESD-associated currents in order to develop test simulators. Significantly less work has been done on the ESD-radiated fields. This paper examines the fields problem, both theoretically and experimentally. Measurements indicate that the electric fields can be quite significant (>150 V/m at a distance of 1.5 m), particularly for relatively low voltage sparks (<6 kV). A theoretical dipole model for the ESD spark is developed to compute the radiated fields if the required current waveform can be modeled based on

Radiated EMI (cont'd.)

measurements. The agreement between theory and experiment is good. The model may be used to predict the fields for a wide range of possible discharge configurations.
[Contact: Mark T. Ma, (303) 497-3800]

Conducted Electromagnetic Interference

Released for Publication

Martzloff, F.D., **Power Quality Standards**, to be published in the Proceedings of the Power Electronic Applications Center Conference, Knoxville, Tennessee, October 25, 1987.

The issue of power quality has recently become more pressing as more sensitive load equipment is being installed by all end-users of electric power. The issue has also become more pressing because some of the new load equipment circuits create disturbance within the end-user system. Mechanisms leading to poor quality in the power supply are well known among power system engineers, but new concerned parties are emerging as applications of the new equipment introduce these newcomers to the old problems. This increasing awareness can take the form of adversarial relations between power supplier (the electric utilities) and power user (the end-users: industry, commerce, and consumer). These adversarial positions are in part rooted in incomplete knowledge of the mechanisms of disturbances and of the facts concerning their mitigation. In some instances, subjective reactions creep into the process of dealing with a technical problem. Standards addressing these concerns can provide the necessary degree of objectivity and reconcile adversaries by developing a consensus based on reliable, safe, and cost-effective solutions.
[Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., **Discussion by F.D. Martzloff of IEEE PES Paper 88 SM 541-5, "Steep-Front Short-Duration Voltage Surge Tests of Power Line Filters and Transient Voltage Suppressors."**

The authors report interesting results of their tests on commercial filters (presumably consisting of linear elements), enhanced by two types of nonlinear surge-protective devices. While there is no problem with the reported performance per se, the wording of the report summary suggests an inconsistency in reporting otherwise accurate results.
[Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., **Tigers or Pussycats-Does Distance Make the Difference?**

The first of a two-part update is presented on progress at the National Institute of Standards and Technology in a study on the propagation of surges in building wiring systems. Part 1 provides information on the organization of an informal consortium to sponsor the work and makes reference to an IEEE paper scheduled for presentation in September 1988. Part 2, to be submitted later, will describe further work.
[Contact: Francois D. Martzloff, (301) 975-2409]

Recently Published

Martzloff, F.D., **Surge Testing: Don't Kid Yourself, Don't Kill Yourself**, EMC Technology and Interference Control News, Vol. 7, No. 5, pp. 35-38 (July-August 1988).

Increasing awareness of the sensitivity of electronics to surge effects has led to a proliferation of surge suppressors on the market. Confronted with a difficult choice, some users are evaluating the performance of these devices by surge testing. However, the techniques involved in these tests are different from typical electromagnetic compatibility (EMC) testing because of the single-shot nature of the event and

Conducted EMI (cont'd.)

because of the potential personal hazards involved in surge testing. This article presents a brief overview of surge testing, focusing on the techniques required in performing valid tests under safe conditions.
[Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., and Leedy, T.F., **Electrical Fast Transient Tests: Applications and Limitations**, Proceedings of the IEEE Industrial Applications Society 35th Annual Petroleum & Chemical Industry Conference, Dallas, Texas, September 12-14, 1988 (Institute of Electrical and Electronics Engineers, Inc., New York, New York, September 1988), pp. 1-8.

The Technical Committee TC 65 of the International Electrotechnical Commission (IEC) has promulgated a new document (IEC 801-4) requiring demonstration of the immunity of industrial process control equipment to fast transients occurring in power and data lines. These fast transients contain high-frequency components, intuitively expected to suffer greater attenuation than the lower-frequency components as they propagate along the lines. Quantifying this intuitive expectation provides a perspective on the severity of the situation and helps in defining realistic test requirements. To that end, this paper describes specific measurements conducted for typical low-voltage power line configurations; modeling of the attenuation provides a tool for understanding the significance of the line parameters and extends the usefulness of results to general cases.
[Contact: Francois D. Martzloff, (301) 975-2409]

ADDITIONAL INFORMATION

DC & Low Frequency Metrology

Released for Publication

Field, B.F., and McCaleb, M.R., **An Improved Transportable DC Voltage Standard.**

Zener-diode-based dc voltage standards can be excellent transport standards for the unit of dc voltage because of their resistance to physical shock and temperature changes. The problems of transporting a unit of voltage and the properties of available Zener standards were studied to develop a set of characteristics that we consider to be essential for an optimum transport standard. We report some of the results of this requirements study, explain the design of our improved transport standard, discuss our efforts to select Zener diodes for the standard, and present data obtained from prototype Zener reference modules to be used in the standard.
[Contact: Bruce F. Field, (301) 975-4230]

Kinard, J.R., and Lipe, T.E., **Recharacterization of Thermal Voltage Converters After Thermoelement Replacement.**

The relationship between the characteristics of various thermoelements (TEs) as voltage or current converters and the overall ac-dc differences of a voltage range in a coaxial thermal voltage converter (TVC) set is described. An algorithm to predict the relationships between the ac-dc differences of individual voltage ranges with different TEs is presented, and a method for recharacterizing a thermal voltage converter containing a replacement TE is given. The measured results show that for most applications, a complete recharacterization of the TVC set is unnecessary.
[Contact: Joseph R. Kinard, (301) 975-4250]

Steiner, R.L., and Field, B.F., **Josephson Array Voltage Calibration System: Operational Use and Verification.**

DC & Low Frequency Metrology (cont'd.)

A new Josephson array system now maintains the U.S. Legal Volt. This system is almost fully automated, operates with a typical precision of 0.009 μV, and readily allows U.S. Legal Volt measurements weekly, or more frequently if desired. This system was compared to the previous volt maintenance system, and both systems agreed to within 0.03 ppm. This verification is limited by uncertainties in the resistive divider instruments of the previous system.
[Contact: Richard L. Steiner, (301) 975-4226]

Recently Published

Field, B.F., and Ruimin, L., **An Improvement in the Reliability of Standard Cell Enclosures**, Journal of Research of the National Bureau of Standards, Vol. 93, No. 4, pp. 533-537 (July-August 1988).

We describe the design of a new temperature-regulation circuit, which is used as an outer oven controller for new standard cell enclosures, with the emphasis on improving the reliability of the temperature control. A redundant protection circuit is used to prevent loss of temperature control caused by component failures in the controller. The temperature control of the outer oven of the enclosure is better than 0.4 mK per °C change in ambient temperature. When used with the additional inner controller, the sensitivity of the cell temperature to the ambient temperature is improved to 20 μK/°C. This paper describes in detail the new circuit, summarizes the enclosure construction, and presents data on the performance of the system.
[Contact: Bruce F. Field, (301) 975-4230]

Peterson, R.L., and Oldham, N.M., **Josephson ac Voltmeter**, Journal of Applied Physics, Vol. 63, No. 10, pp. 4804-4810 (May 15, 1988).

A technique for accurate measurement of ac voltages with Josephson junctions is described. Based on the counting of pulses generated by a Josephson junction, the method may be capable of precision at the ppm level for frequencies less than 100 kHz.
[Contact: Robert L. Peterson, (303) 497-3750]

Turgel, R.S., Mulrow, J.M., and Vecchia, D.F., **NBS Phase Angle Calibration Services**, NBS Special Publication 250-26 (May 1988).

The National Institute of Standards and Technology/NIST (formerly National Bureau of Standards/NBS) offers a calibration service for audio-frequency phase meters. The calibrations are based on a phase angle standard developed at NIST that generates two sinusoidal signals displaced relative to each other by a precisely known phase angle over a frequency range of 2 Hz to 50 kHz. The signal amplitudes are independently adjustable on each channel from 0.5 to 100 V. The angular resolution is better than 0.002° at the low end of the frequency range and decreases to 0.005° at the high end. The uncertainty of the phase angle between the two signals generated by the standard varies from 0.005° to 0.04°, depending on frequency and amplitude.

Using the phase angle standard, phase meter readings are obtained at selected test points. From the calibration data, the phase meter response characteristic is determined and is compared to that of an ideal meter having a linear characteristic. If the phase meter response conforms to the linear model, a straight-line calibration curve is derived from the data and serves to calculate corrected readings. From the statistical parameters associated with the calibration curve, it is possible to estimate the limits of offset between the calibrated meter and the calibration standard. By extension, the uncertainty of readings of the phase meter in the user's laboratory can be estimated.

DC & Low Frequency Metrology (cont'd.)

[Contact: Raymond S. Turgel, (301) 975-2420]

Fundamental Electrical Measurements

Released for Publication

Cage, M.E., Dziuba, R.F., Elmquist, R.E., Field, B.F., Jones, G.R. Jr., Olsen, P.T., Phillips, W.D., Shields, J.Q., Steiner, R.L., Taylor, B.N., and Williams, E.R., **NIST Determination of the Fine-Structure Constant, and of the Quantized Hall Resistance and Josephson Frequency to Voltage Quotient in SI Units.**

Results from NIST experiments to realize the ohm and the watt, to determine the proton gyromagnetic ratio and the time dependence of the NIST ohm using the quantum Hall effect, and to maintain the NIST volt using the Josephson effect are appropriately combined to obtain an accurate value of the fine-structure constant and of the quantized Hall resistance in SI units, and values in SI units of the Josephson frequency to voltage quotient, Planck constant, and elementary charge.
[Contact: Barry N. Taylor, (301) 975-4220]

Olsen, P.T., Elmquist, R.E., Phillips, W.D., Williams, E.R., Jones, G.R. Jr., and Bower, V.E., **A Measurement of the NIST Electrical Watt in SI Units.**

We have measured the NIST electrical watt in SI units to be: $W_{NIST}/W = K_W = 1 - (16.69 \pm 1.33)$ ppm. The uncertainty of 1.33 ppm has the significance of a standard deviation and includes our best estimate of random and known or suspected systematic uncertainties. The mean time of the measurement is 15 May 1988. Combined with the recent measurement of the NIST ohm in SI units: $\Omega_{NIST}/\Omega = K_\Omega = 1 - (1.593 \pm 0.022)$ ppm, this leads to a Josephson frequency/voltage quotient of $E_j = E_o$ [1 + (7.94 ± 0.67) ppm] where E_o = 483594 GHz/V.
[Contact: P. Thomas Olsen, (301) 975-6553]

Shields, J.Q., Dziuba, R.F., and Layer, H.P., **New Realization of the Ohm and Farad Using the NIST Calculable Capacitor.**

Results of a new realization of the ohm and farad using the NIST calculable capacitor and associated apparatus are reported. The results show that both the NIST unit of resistance and the NIST unit of capacitance are changing with time, Ω_{NIST} at the rate of -0.054 ppm/year and F_{NIST} at the rate of 0.010 ppm/year. The realization of the ohm is of particular significance at this time because of its role in assigning an SI value to the quantized Hall resistance. The estimated uncertainty of the ohm realization is 0.022 ppm (1σ), while the estimated uncertainty of the farad realization is 0.014 ppm (1σ).
[Contact: John Q. Shields, (301) 975-4223]

Williams, E.R., Jones, G.R. Jr., Sheng, Y., Ruimin, L., Sasaki, H., Olsen, P.T., Phillips, W.D., and Layer, H.P., **A Low Field Determination of the Proton Gyromagnetic Ratio in Water.**

We measure the proton gyromagnetic ratio in H_2O by the low-field method, γ'_p(low). The result, γ'_p(low) = 2.67513376 10^8 s^{-1} T^{-1}_{NIST} (0.11 ppm), leads to a value of the fine structure constant of α^{-1} = 137.0359840 (0.037 ppm) and a value for the quantized Hall resistance in SI units of R_H = 25812.80460 Ω (0.037 ppm). To achieve this result, we measured the dimensions of a 2.1-m solenoid with an accuracy of 0.04 μm, and then measured the NMR frequency of a water sample in the field of the solenoid.
[Contact: Edwin R. Williams, (301) 975-6555]

Lists of Publications

Reidy, A.M., and Gibson, K.A., **A Bibliography of the NIST Electromagnetic Fields Division Publications**, NISTIR 88-

Lists of Publications (cont'd.)

3900 (September 1988).

This bibliography lists publications by the staff of the National Bureau of Standards' Electromagnetic Fields Division for the period from January 1970 through August 1988. Selected earlier publications from the Division's predecessor organizations are included. [Contact: Kathryn A. Gibson, (303) 497-3132]

Kline, K.E., and DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NBS Publications**, NBSIR 87-3074 (June 1987).

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NBS in the period from January 1970 through December 1986. A few earlier references that are directly related to the present work of the Division are included.
[Contact: Sarabeth Moynihan, (303) 497-3678]

Palla, J.C., and Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NBS Electrosystems Division Publications, NBS List of Publications 94** (January 1988).

This bibliography covers publications of the Electrosystems Division, Center for Electronics and Electrical Engineering, NBS, and of its predecessor sections for the period January 1963 to January 1988. A brief description of the Division's technical program is given in the introduction.
[Contact: Jenny C. Palla, (301) 975-2220]

Walters, E.J., **Semiconductor Measurement Technology, NBS List of Publications 72** [a bibliography of NBS publications concerning semiconductor measurement technology for the years 1962-1987] (March 1988).

This bibliography contains reports of work performed at the National Bureau of Standards in the field of Semiconductor Measurement Technology in the period from 1962 through December 1987. An index by topic area and a list of authors are provided.
[Contact: E. Jane Walters, (301) 975-2050]

R&D 100 AWARD WINNER

Image-Preseving Optical Delay

Edward F. Kelley of the Electrosystems Division is the recipient of an R&D 100 Award in 1988 for developing the first practical optical system capable of providing high-quality images with significant delays and applied it to the analysis of nanosecond-scale electrical discharge events. The delay system uses one 0.3-m diameter concave mirror and a special array of smaller mirrors located about 4 m from the concave mirror to provide a delay of up to 390 ns, based on the travel time of light reflected some thirty times between the mirrors. Diffraction and astigmatism effects make it impractical to achieve such a delay in an image-preserving system with either a single-reflection system with the mirrors widely spaced or a conventional folded-beam mirror arrangement. While others have demonstrated single-pass image-preserving optical systems providing short delays, the Division believes that the NIST system is the first to provide useful delays of over 100 ns. The system is part of new apparatus for examining the onset of nonosecond-scale electrical discharges. The challenge is akin to that of taking picutres of lightning with only a fast shutter speed available: you don't know when the lightning discharge will occur. In this case, the shutter speed is as fast as 1/100,000,000 of a second. In collaboration with a team from the University of Tennessee (UT), the Division has developed a system for taking pictures of these very fast discharge events as they develop. The UT team designed a special amplifier that detects the initial rise in current

Image-Preserving Optical Delay (cont'd.)

as the discharge begins. By the time the discharge is detected, it is too late to actuate even the very fast Pockels-cell camera shutter designed by Division Guest Worker, M. Nehmadi. The delay system solves this problem by storing the image long enough to allow the camera to record it. The Division believes the delay system will have wide applicability in the study of randomly occurring nanosecond- and subnanosecond-scale events and has applied for a patent.
[Contact: Robert E. Hebner, (301) 975-2659]

RECENTLY ISSUED STANDARD REFERENCE MATERIALS

The Semiconductor Electronics Division announces the release of a new Standard Reference Material (SRM) for **ellipsometrically derived thickness and refractive index of a silicon dioxide film on silicon**. Available for sale to the public through the NIST Office of Standard Reference Materials [for orders, (301) 975-6776], SRM 2530 is separately available for three oxide thicknesses: 50 nm (2530-1), 100 nm (2530-2), and 200 nm (2530-3).

This SRM was developed to respond to industry needs to evaluate the accuracy of ellipsometers, but may also be used as aid in the calibration of various other optical and mechanical thickness monitoring instruments.

Each SRM consists of a 76-mm (3-in.) diameter silicon wafer on which a uniform silicon dioxide layer was grown, patterned, and partially covered with chromium. The certified values were determined from measurements made using the highly accurate ellipsometer developed in the Division and are the ellipsometric parameters delta, Δ, and psi, ψ, at a wavelength of $\lambda = 632.8$ nm. The SRMs are also certified for the derived values of thickness and refractive index of its silicon dioxide layer determined by using a two-layer model consisting of a silicon dioxide layer on a thin silicon-rich oxide interlayer. [Contact: Deane Chandler-Horowitz, (301) 975-2084]

1989 CEEE CALENDAR

February 7-9, 1989 (San Diego, CA)

IEEE Semiconductor Thermal and Temperature Measurements Symposium. This fifth annual **SEMI-THERM** symposium is sponsored by the Components, Hybrids, and Manufacturing Technology Society of IEEE in cooperation with NIST and constitutes an international forum for the presentation of new developments relating to generation and removal of heat within semiconductor devices, measurement of device temperatures, and the simulation of device and system thermal behavior. Major SEMI-THERM topic areas include: thermal measurements; simulation, computation, and software; thermal characterization; and applications.

The program includes keynote speakers, technical presentations, tutorial sessions, workshops, and an exhibit. In addition, the Semiconductor Equipment and Materials Institute (SEMI) and the Joint Electron Devices Engineering Council (JEDEC) have scheduled in conjunction with SEMI-THERM several Standards Committee Task Force meetings, to which attendees are invited. [Contact: Frank F. Oettinger, (301) 975-2054]

June 12-15, 1989 (Gaithersburg, MD)

International Conference on Narrow Gap Semiconductors and Related Materials. Jointly sponsored by the National Institute of Standards and Technology, the U.S. Air Force Office of Scientific Research, the American Physical Society, National Science Foundation, the U.S. Office of Naval Research, Texas Instruments, and the University of North Texas, this conference is the first in the narrow gap field since 1981. The

CEEE Calendar (cont'd.)

scope of the conference includes such topics as crystal growth and new materials; two-dimensional physics; surfaces and interfaces; superlattices and heterostructures; transport; impurities and defects; optical properties; nonlinear optical effects; device physics; lattice properties; and hot or nonequilibrium carrier effects. [Contact: David G. Seiler, (301) 975-2081]

September 11-13, 1989 (Garmisch-Partenkirchen, FDR)

VLSI and GaAs Chip Packaging Workshop. The IEEE CHMT Society and the National Institute of Standards and Technology are co-sponsoring the Eighth VLSI Packaging Workshop. Topics to be discussed include VLSI package design; integrated package design; multichip module design; WSI packaging; package thermal design; package electrical design; GaAs IC packaging; VLSI package interconnection options; VLSI package materials and die-attach solutions; and failure mechanism and quality of VLSI packages. All attendees are expected to be specialists working in the field and to participate in discussions. [Contact: George G. Harman, (301) 975-2097]

December 10-11, 1989 (Gaithersburg, MD)

Power Semiconductor Devices Workshop. This Workshop, sponsored jointly by IEEE and NIST, is intended to bring together for interactive participation those actively working in the field of power semiconductor devices. It will be held in conjunction with the 1989 IEEE International Electron Devices Meeting in Washington, DC. Four specific topic areas have been selected: power and high voltage integrated circuits, discrete devices, device and circuit simulation, and packaging. In addition, a special panel on power electronics education will be held. This year's Workshop will specifically solicit attendance from device and circuit users as well as device researchers. Attendees are expected to be prepared to contribute to the development of responses to specific questions that arise in the context of the particular topic areas; a final schedule should be available at the end of October. [Contact: David L. Blackburn, (301) 975-2068]

CEEE SPONSORS

National Institute of Science and Technology

U.S. Air Force
Newark Air Force Station; Rome Air Development Center; Space & Missile Organization; U.S. Air Force Headquarters; Wright-Patterson Air Force Base; Technical Applications Center (Patrick); Kirtland AFB; Electronics Security Command

U.S. Army
Fort Belvoir; Fort Monmouth; Fort Huachuca; Harry Diamond Laboratory; Materials & Mechanics Research Center; Redstone Arsenal; Strategic Defense Command; AVRADCOM (Aviation)

Department of Commerce
Patent and Trademark Office

Department of Defense
Defense Communication Agency; Defense Nuclear Agency; Defense Advanced Research Projects Agency; National Security Agency; Combined Army/Navy/Air Force (CCG)

Department of Energy
Energy Systems Research; Fusion Energy; High Energy & Nuclear Physics; Bonneville Power Administration

Department of Justice
Law Enforcement Assistance Administration

U.S. Navy
Naval Ocean Systems Center; Weapons Support Center/Crane; Naval Weapons Station; Office of Naval Research; Naval Sea Systems Command; Naval Postgraduate School; Naval Ship Research Development Center; Naval Air Systems Command; Naval Research Laboratory; Naval Surface Warfare Center; Aviation Logistics Center/Patu-

CEEE Sponsors (cont'd.)

xent; Naval Explosive Ordnance Disposal Technology Center
National Science Foundation
National Aeronautics and Space Administration
Goddard Space Flight Center; Lewis Research Center
Nuclear Regulatory Commission
Department of Transportation
National Highway Traffic Safety Administration
Non-Federal Government Sponsors
Sandia National Laboratories

☆U.S.GOVERNMENT PRINTING OFFICE:1989-242-200/00001

NBS-114A (REV. 2-8C)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO. NISTIR 88-4020	2. Performing Organ. Report No.	3. Publication Date January 1989

4. TITLE AND SUBTITLE

Center for Electronics and Electrical Engineering Technical Progress Bulletin Covering Center Programs, July to September 1988, with 1989 CEEE Events Calendar

5. AUTHOR(S)

E. Jane Walters, compiler

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

NATIONAL BUREAU OF STANDARDS
U.S. DEPARTMENT OF COMMERCE
GAITHERSBURG, MD 20899

7. Contract/Grant No.

8. Type of Report & Period Covered

July-September 1988

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)

10. SUPPLEMENTARY NOTES

All technical information included in this document has been approved for publication previously.

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This is the twenty-fourth issue of a quarterly publication providing information on the technical work of the National Institute of Standards and Technology (formerly the National Bureau of Standards) Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Progress Bulletin covers the third quarter of calendar year 1988. Abstracts are provided by technical area for both published papers and papers approved by NIST for publication.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

antennas; electrical engineering; electrical power; electromagnetic interference; electronics; instrumentation; laser; magnetics; microwave; optical fibers; semiconductors; superconductors

13. AVAILABILITY

☒ Unlimited

☐ For Official Distribution. Do Not Release to NTIS

☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

38

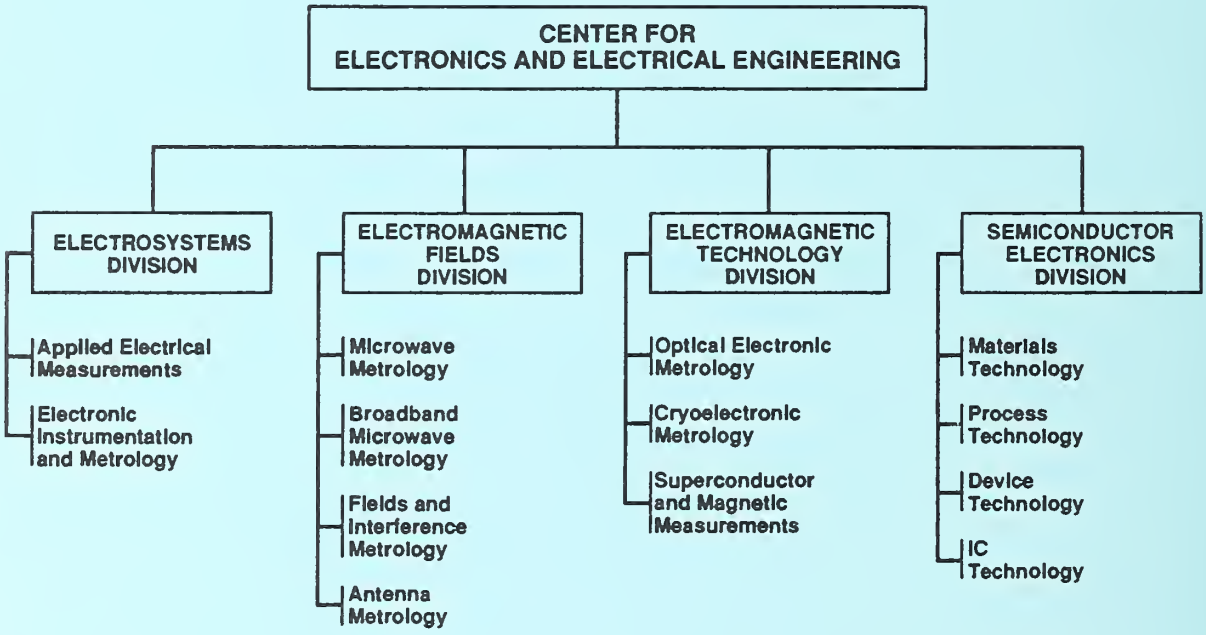
15. Price

$12.95

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MD 20899
RETURN POSTAGE GUARANTEED

BULK RATE
POSTAGE & FEES PAID
NIST
PERMIT No. G195

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300



KEY CONTACTS:

Center Headquarters (720)	Director, Mr. Judson C. French (301) 975-2220
	Deputy Director, Mr. Robert I. Scace (301) 975-2220
Electrosystems Division (722)	Chief, Dr. Oskars Petersons (301) 975-2400
Electromagnetic Fields Division (723)	Chief, Dr. Ramon C. Baird (303) 497-3131
Electromagnetic Technology Division (724)	Chief, Dr. Robert A. Kamper (303) 497-3535
Semiconductor Electronics Division (727)	Chief, Mr. Frank F. Oettinger (301) 975-2054

INFORMATION:

For additional information on the Center for Electronics and Electrical Engineering, write or call:

Center for Electronics and Electrical Engineering
National Institute of Standards and Technology
Metrology Building, Room B-358
Gaithersburg, MD 20899
Telephone (301) 975-2220